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NAVPERS 93375

GYROS, MAINTENANCE AND SUPPLY

STANFORD UNIVERSITY
MAR 1966
GOV'T DOCUMENT DIVISION

TRAINEE'S GUIDE

for

FIRE CONTROL TECHNICIAN TRAINING

MARCH 1966

BUREAU OF NAVAL PERSONNEL

CODE OF CONDUCT
FOR MEMBERS OF THE ARMED FORCES OF THE UNITED STATES

THE CODE

I

I am an American fighting man. I serve in the forces which guard my country and our way of life. I am prepared to give my life in their defense.

II

I will never surrender of my own free will. If in command I will never surrender my men while they still have the means to resist.

III

If I am captured I will continue to resist by all means available. I will make every effort to escape and aid others to escape. I will accept neither parole nor special favors from the enemy.

IV

If I become prisoner of war, I will keep faith with my fellow prisoners. I will give no information nor take part in any action which might be harmful to my comrades. If I am senior, I will take command. If not, I will obey the lawful orders of those appointed over me and will back them up in every way.

V

When questioned, should I become a prisoner of war, I am bound to give only name, rank, service number, and date of birth. I will evade answering further questions to the utmost of my ability. I will make no oral or written statements disloyal to my country and its allies or harmful to their cause.

VI

I will never forget that I am an American fighting man, responsible for my actions, and dedicated to the principles which made my country free. I will trust in my God and in the United States of America.

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE NAVY
BUREAU OF NAVAL PERSONNEL
WASHINGTON, D.C. 20370

1 December 1965

GYROS, MAINTENANCE AND SUPPLY
TRAINEE'S GUIDE
NAVPERS 93375

1. This publication and the companion Instructor's Guide, NavPers 93374, are the approved curriculum for the block of instruction concerning gyroscopes, Navy Maintenance Management System and Navy Supply System in Navy Fire Control Technician Schools, Class "A", and are effective upon receipt.

2. Corrections and recommended changes to this publication are invited. Commanding Officer, U. S. Naval Schools Command, Mare Island, Vallejo, California, 94592, has been assigned clearing house responsibility for evaluating and compiling recommended improvements, and for submitting them to the Chief of Naval Personnel in the form of a proposed change to the publication. Users of this course material are requested to submit their recommendations directly to the command having clearing house responsibility, with a copy to the Chief of Naval Personnel (Attn: Pers-C12). No deviations from this curriculum are authorized until approved by the Chief of Naval Personnel.

3. This publication does not supersede any existing publication.

G. M. METZE, Captain, USN
Director, Weapons Systems and
Fleet Training Division

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SAFETY NOTICE

WARNING

The attention of all hands is directed to Section V, Chapter 67 of Bureau of Ships Technical Manual or superseding instructions on the subject of safety.

Dangerous voltages are employed in the training devices and equipments used throughout this course. Contact with live circuits can result in permanent injury or death.

NEVER MEASURE POTENTIALS OVER 600 VOLTS BY MEANS OF FLEXIBLE TEST LEADS OR PROBES.

DO NOT SERVICE OR ADJUST ALONE:

Under no circumstances should any person work on live equipment without the immediate presence or assistance of another person capable of rendering aid.

DO NOT TAMPER WITH INTERLOCKS.

NOTES

(A) MAKE SURE you are NOT GROUNDED whenever working near or using test equipment on live circuits.
(B) In general, USE ONE HAND only when working around live circuits.
(C) ALWAYS ground the metal case of test equipment before using.
(D) DO NOT FORGET that high voltages MAY BE PRESENT across terminals that are normally low voltage due to component breakdown or equipment malfunction. Use care even when measuring low voltages.
(E) NEVER USE electrical or electronic equipment known to be in poor condition.
(F) ALWAYS inspect test leads, line cords, etc., to insure that no cracked or broken insulation, frayed wires or loose connections exist, before using any portable electrical or electronic equipment.
(G) High-voltage, high-capacity capacitors should be discharged with a suitably insulated shorting or grounding bar with about 10 ohms in series with the grounded line. Where neither terminal of a capacitor is grounded, short the terminals to each other.

RESUSCITATION

Approved posters illustrating the correct procedures and listing rules for resuscitation must be displayed prominently in each fire control, radio, radar, or sonar enclosure. These posters may be obtained upon request to the Bureau of Medicine and Surgery. Formerly, manual methods of artificial respiration were used exclusively. These methods include the prone pressure method, the hip lift-back pressure method, the arm lift-chest pressure method, the arm lift-back pressure method, and Eve's method (rocking on a stretcher). More recently, the "rescue breathing" methods have come into prominent use. These latter methods represent the most efficient means of resuscitation without the use of special equipment, and include mouth-to-mouth, mouth-to-nose, and mouth-to-mouth-and-nose techniques.

Mouth-to-mouth resuscitation is accomplished by sealing one's mouth over the patient's mouth, pinching the nostrils shut, and blowing until his chest lifts—an indication that his

SAFETY NOTICE (Continued)

lungs are filled with air. The air is then allowed to escape, and the procedure is repeated at the normal rate of breathing until the patient can breathe for himself.

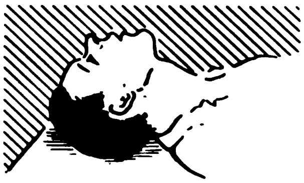
Resuscitation using the patient's nose for an airway is as satisfactory as the mouth-to-mouth method. It is the method preferred by many. When this method is used, the patient's mouth is held closed as air is blown into the nose.

Both the nose and mouth may be used as the patient's airway. This method is, in fact, quite often used when administering resuscitation to infants.

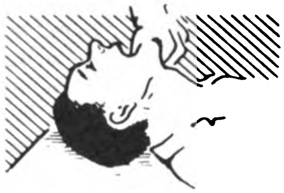
SUMMARY OF STEPS USED IN RESCUE BREATHING:

1. Start the process immediately.
2. Place the patient on his back.
3. Clear the mouth and throat of debris.
4. Tilt the patient's head back.
5. Pull the patient's chin forward, using the middle fingers, so that the lower jaw is literally lifted and it "juts out". This step is necessary to keep the tongue out of the air passage. The lifting is accomplished by placing fingers beneath the jawbone and behind it on a line almost perpendicular to the ear. Using one hand, hold the jaw in this position.
6. Blow air through mouth or nose (or both) until chest rises. (Nostrils should be pinched with fingers if mouth-to-mouth method is used.)
7. Remove your mouth and listen for snoring and gurgling—signs of throat obstruction. If the throat is obstructed, turn the patient quickly on his side and administer several blows between the shoulder blades in an effort to dislodge the obstruction.
8. The complete cycle of filling the patient's lungs with air and allowing them to deflate should be smooth, with each complete cycle starting at approximately five-second intervals.
9. Continue rescue breathing until the patient breathes for himself.

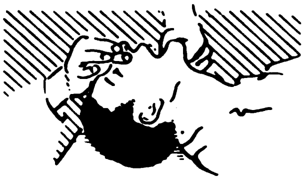
SAFETY NOTICE (Continued)



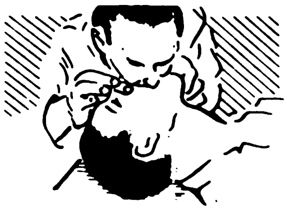
1. THRUST HEAD BACKWARDS



2. LIFT TONGUE AND JAW



3. PINCH NOSTRILS



4. BLOW INTO PATIENT'S MOUTH

Although rescue breathing is the preferred method for administering artificial respiration, the technician should be skilled in other methods in order to manage situations where rescue breathing cannot be used. The method to be used is dictated by the condition of the patient, the availability of equipment and trained personnel, and the particular environment.

There are procedures applicable to all methods of resuscitation. The first thing is to begin immediately by putting the patient in the proper position. Do not wait for help or equipment. Since every second counts, start the resuscitation and attend to secondary measures as you proceed. The important thing is to establish and maintain the rhythm of artificial respiration without interruption. Matters such as clearing debris from the mouth, pulling out a swallowed tongue, keeping the area about the mouth clear so that no foreign matter is taken in, loosening clothing which restricts breathing, removing wet clothing and keeping the patient warm are vital, but they should be done without interrupting the rhythm.

The patient should not be given any food or liquid until he is fully conscious. The artificial respiration should be performed on the scene if possible. Once breathing is restored, the patient should be transported on a stretcher for further medical attention.

HOW TO USE THIS TRAINEE'S GUIDE

PUBLICATION

This Trainee's Guide has been prepared for use in Navy technical schools teaching the fundamentals of gyroscopes, Navy Maintenance Management System and the Naval Supply System.

TRAINING GOALS

This course material is divided into sections which are further divided into topics. The training goals are stated at the beginning of each topic, with a brief outline of the discussion points to be covered by the instructor.

STUDY ASSIGNMENTS

Self-study assignments serve to supplement classroom instruction. The trainee is urged to reinforce his knowledge by reading study assignments during class study periods or when otherwise scheduled by the instructor.

QUIZ SHEETS

A quiz at the end of each section is to be completed as directed by the instructor. Do not mark this book - write your answers on a separate sheet of paper.

SAFETY PRECAUTIONS

Read the SAFETY NOTICE carefully. Develop safe working habits and practice safety always. Take time to be safe.

RECORD OF CHANGES

Number or Description of Change	Made by	Date

Section 1

GYROSCOPE FUNDAMENTALS

Topic No.	Topic Title	Page
1.	Basic Principles of Gyroscopes	2
2.	Classifications and Mechanics of Gyroscopes	8
3.	Applications	22

TOPIC 1: BASIC PRINCIPLES OF GYROSCOPES

YOU ARE NOW GOING TO LEARN:

1. The origin and definition of gyroscopes.
2. The basic properties of gyroscopes.
3. The basic gyroscope components.
4. The effect of rotation of the earth and how it is compensated.
5. The causes and effect of mechanical drift and its compensation.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Origin of gyroscopes.
2. Definition of gyroscopes.
3. Basic properties of gyroscopes:
   a. Rigidity.
   b. Precession.
4. Basic gyroscope components.
5. Effect of rotation of the earth.
6. Latitude correction.
7. Effect of mechanical drift.
8. Causes of mechanical drift:
   a. Unbalance.
   b. Bearing friction.
   c. Inertia of gimbals.
9. Compensation for mechanical drift.
10. Review and summary.

INFORMATION AND DISCUSSION:

The study of gyroscope fundamentals is a new field to the trainee. This course will deal with the basic principles and applications of gyroscopes rather than on details of construction, repair, and maintenance. A good knowledge of gyroscope fundamentals cannot be attained by simply reading about them. Gyroscope demonstrators will be used throughout the course.

Gyroscopes are widely used in fire control and missile systems. Gyroscopes are used to provide stabilized information for fire control systems as the ship pitches and rolls. Gyroscopes may also be used to stabilize the movement of a whole radar antenna or provide a stable reference platform in missiles.

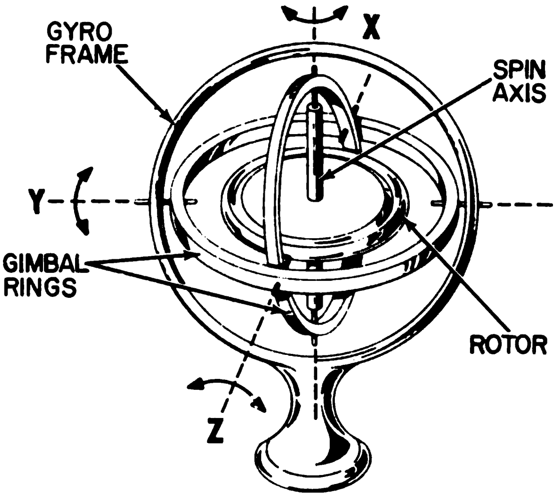
You as a Fire Control Technician will find more places where you will work with gyroscopes. There is nothing really complicated about them and they do not present a serious maintenance problem, however, one thing should be remembered; gyroscopes are expensive items to replace. DO NOT USE THEM AS TOYS.

ORIGIN AND DEFINITION OF GYROSCOPES

The gyroscope, commonly called a gyro, is the oldest natural mechanism in the universe. It has existed ever since the first electron was sent spinning on its axis. Yes, electrons spin and show all the characteristics of a gyroscope. Any rapidly spinning object - a top, wheel, propeller, a spinning projectile,or the earth itself is fundamentally a gyroscope. The earth spins about its polar axis at a very high speed. It is interesting to note that any point on the equator travels at a speed of over 1000 miles per hour, which is about three times as fast as the rotational speed of gyros with which you will be working.

The word gyroscope was first coined by the French scientist, Leon Foucault in 1852. Foucault made his first gyroscope for the purpose of demonstrating the rotation of the earth. The word gyroscope is derived from the Greek words "gyro", meaning revolution and "skopein", meaning to view. Combined, the words mean to view the revolution, or for Foucault's purpose, to view the revolution of the earth.

Although any rapidly spinning object is fundamentally a gyroscope, strictly speaking, a gyroscope may be defined as a mechanical device containing a spinning mass which is free to turn about one or both of two axes perpendicular to each other and to the spin axis. A model of a universally mounted gyro is shown below.



1. GYRO MODEL, UNIVERSALLY MOUNTED

As you can see, a heavy wheel is mounted so that its spin axis is free to turn in any direction. The wheel can spin about axis X, it can turn about axis Y, and finally it can turn about axis Z. With this mechanical arrangement, the spinning wheel can assume any position in space. Thus our model gyro meets the requirements of the definition.

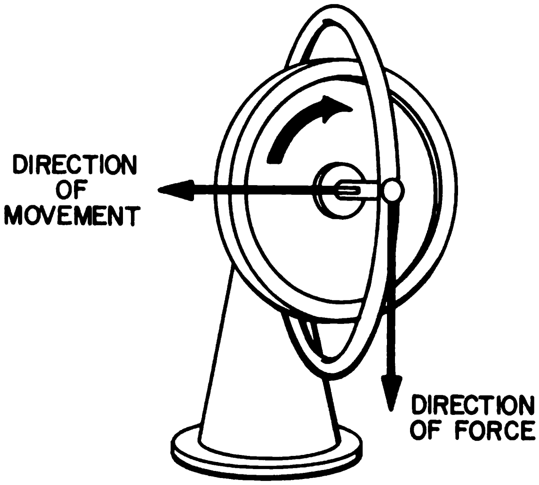
BASIC PROPERTIES OF GYROSCOPES

Gyroscopes have two properties which make them useful in fire control:

1. RIGIDITY - The spin axis of the gyro wheel will remain in a fixed direction in space if no force is applied.
2. PRECESSION - The spin axis has a tendency to turn at right angles to the direction of the applied force.

The idea of maintaining a fixed direction in space is easy to show. When any object is spinning rapidly, it tends to keep its spin axis pointed always in the same direction. A top is a good example. As long as it is spinning fast, it stays balanced on its point. Because of its gyro action, it resists the tendency of gravity to change the direction of the axis. You can think of many more examples. A bicycle is easier to balance at high speeds than when it is barely moving. At high speeds, the wheels act as gyros, and tend to keep their axis parallel to the ground. The amount of rigidity of a gyroscope is a function of: speed of rotation, weight of the spinning wheel, and concentration of the weight. The faster the wheel spins, the heavier the wheel is, and the more the weight is concentrated near the outer rim, the greater the rigidity.

The illustration below represents a gyro with its wheel spinning in the direction indicated by the curved arrow. If a force is applied as shown, the gyro will respond to that force by moving its spin axis in a direction 90 degrees from the direction of the applied force, in the direction of spin.



2. GYRO PRECESSION

The rules of precession can be stated as follows: a gyro will always precess at right angles to the direction of the applied force and in a direction tending to line itself up so that its wheel spins in the same direction that the applied force is trying to turn it. The rate of precession is proportional to the applied force.

You can see that the property of rigidity in space could be invaluable to navigation in space travel. The gyro spin axis could be made to indicate the desired direction of travel and could be used to sense the slightest deviation from the desired course.

In the case of terrestial navigation, the common reference is the north pole. Aboard most ships the type of northward indicating device used is the gyrocompass. As an FT, you will not be required to work on the gyrocompass, but all fire control equipment depends on it for an input of own ship course. Ship course is the direction the ship is heading in relationship to north. You remember that own ship course is necessary to the solution of the fire control problem.

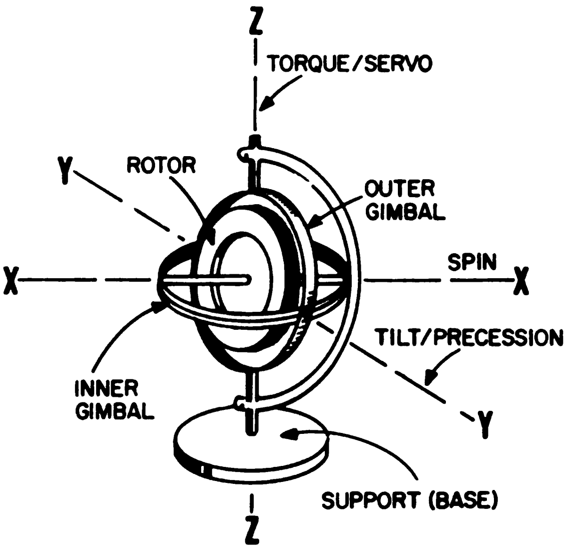
Another application of the property of rigidity is in determining the amount of roll and pitch of the ship as it affects the fire control problem. If a gyro's spin axis is positioned vertical to the earth's surface, it will attempt to remain vertical regardless of the rolling and pitching motion. When used with some type of electronic sensing device, we are able to measure the roll and pitch angles. The measurement of these angles is vital to the solution of any fire control problem, where motion of the firing and controlling platform is involved, such as surface ships, submarines, aircraft, or a tank on land.

One application of the property of precession is in a lead-computing sight. Basically what is done is to use a pair of rate-of-turn gyros which are mounted in such a manner that as the operator positions the sight to follow a target, the gyros tend to precess. The precession is restrained and measured in terms of bearing and elevation tracking rates. These rates, after certain modifications, become gun orders.

BASIC GYROSCOPE COMPONENTS

The gyro shown in the following illustration is a basic universally mounted gyro. The components are: the rotor, the inner gimbal, the outer gimbal, and the base or support. These axes are also defined.

The rotor is the spinning wheel and quite often is the rotor of the motor used to spin the gyro. The terms, wheel and rotor, will be used interchangeably.



3. BASIC UNIVERSALLY MOUNTED GYRO

The term gimbals may be defined as a device for permitting a body to incline freely in any direction and retain that position when the support is tipped or repositioned. Note that the support may be moved about all three axes without the rotor position being disturbed.

Rigidity in space is also clearly shown in fundamental form by this demonstration. Note, too, when the inner and outer gimbals both lie in the same plane, a condition exists, called a gimbal lock. This may cause an undesired effect called tumbling.

The base or support is the device to which the gimbals are mounted. This may be a missile airframe, the case of a gyro mounted aboard a ship, or any other supporting structure. The three major axes of any gyro, such as shown in the above illustration, are the spin, torque or servo, and precession or tilt.

The spin axis is of course the axis on which the rotor spins. The spin axis is also considered the reference axis. The torque or servo axis is the axis about which the disturbing force is applied, whether it is a desirable or undesirable force. The precession or tilt axis is the axis the gyro turns about as a result of the force applied about the torque axis.

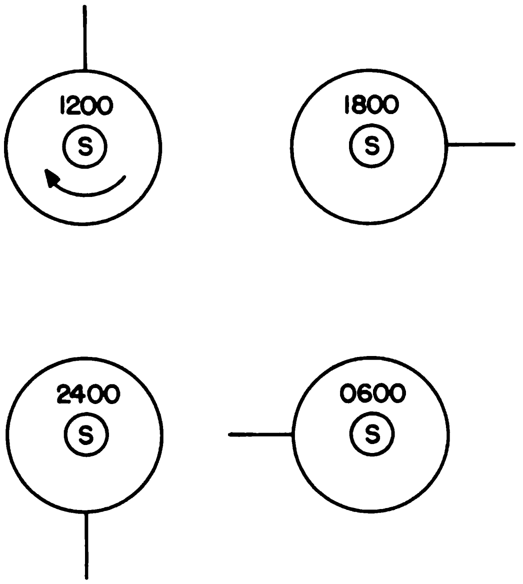
EFFECT OF ROTATION OF THE EARTH AND HOW IT IS COMPENSATED

A gyro maintains its spin axis fixed in space, and not in relation to the earth's surface. To understand this, imagine yourself in a space ship somewhere out in space and looking at the South Pole of the earth. You would see a sphere rotating clockwise, with the South Pole in the center. Maneuver your space ship until it is on a direct line with the axis of the earth through the South Pole and then cut in the automatic controls to keep it in this position. The sphere you see would make a complete rotation every 24 hours.

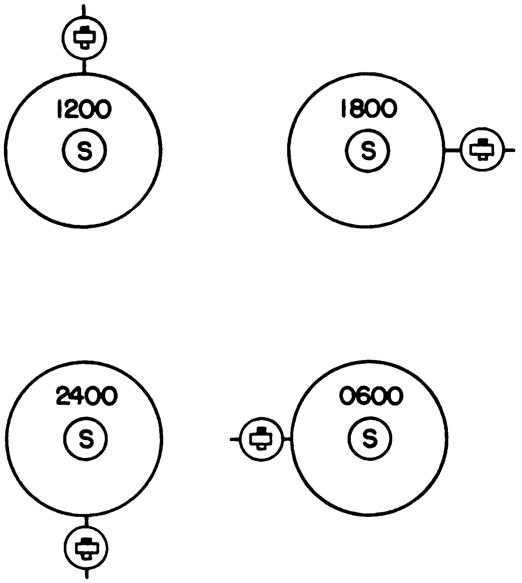
You could keep track of that rotation by driving a big stake into the equator as shown below. If this spot were upright at 1200, the earth's rotation would carry it around so that it would be pointing to the right at 1800. Likewise, the earth's rotation would carry the stake around so that at 1200 the next day the stake would be back at its original position, having been carried, with the earth, through its complete rotation. Notice that the stake has many positions as you observe it because it is attached to the earth's surface and does not have rigidity in space.

If you place a gyroscope in place of the stake, you would see a different action. Imagine, now, a gyroscope instead of a stake mounted at the equator. The gyro is spinning and DOES HAVE RIGIDITY IN SPACE. Looking at the illustration below, at 1200 the spin axis is horizontal to the earth's surface and the black end points upward. At 1800, the spin axis is horizontal to the earth's surface, but the gyro is still spinning in the same plane as before, and the black end is still pointing upward. At 2400, the spin axis is again vertical to the earth. At 0600, the spin axis is again vertical and the black end still points upward. Finally, at 1200 the next day, the gyro is in the same position as when you started. In fact, the gyro wheel spinning on its axis has not changed its direction in space or its plane of spin in being carried through the whole rotation of the earth. This is because the gyro is RIGID IN SPACE.

You have just imagined viewing the gyro from space. Now let's come back to earth and stand right next to the gyro. You cannot see or feel the earth's rotation, but it is

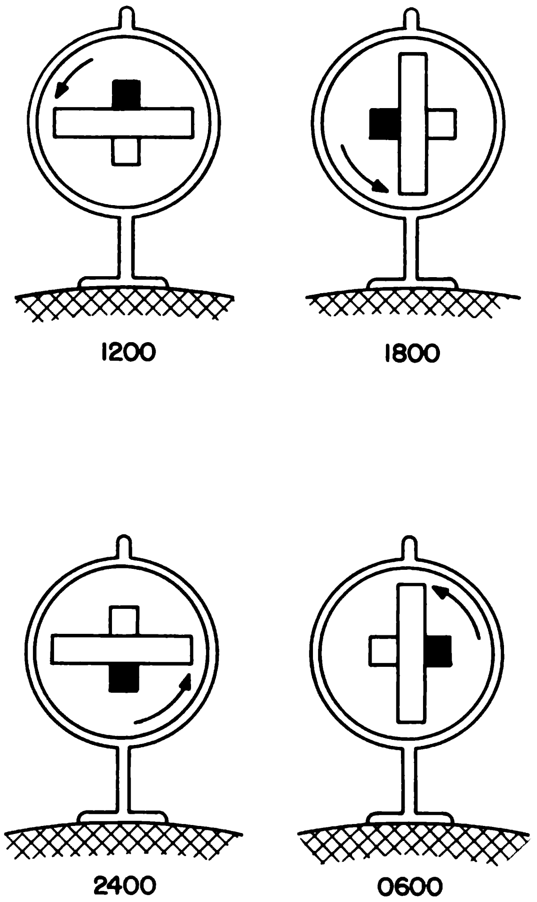


4. STAKE ON EQUATOR VIEWED FROM SPACE



5. GYRO ON EQUATOR VIEWED FROM SPACE ABOVE THE SOUTH POLE

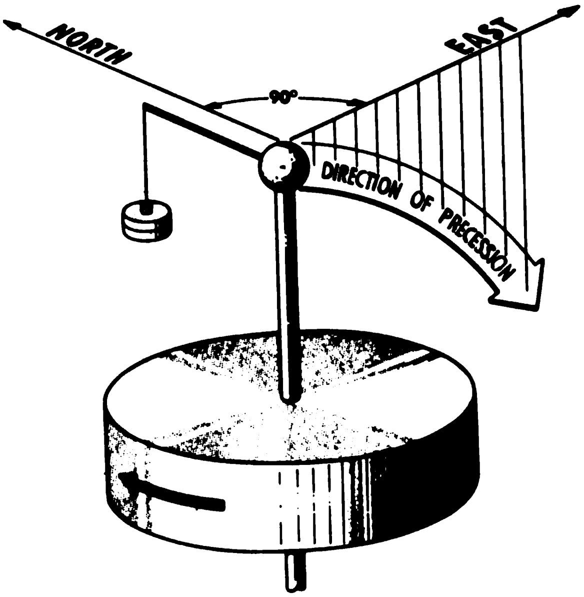
rotating. Looking at the gyro from your viewpoint on earth, the spin axis appears to make one complete rotation in one day. Actually, as you know, the gyro is rigid and both you and the earth are rotating.



6. GYRO ON THE EQUATOR VIEWED FROM EARTH

Latitude correction is the rather misleading name given to the means for compensating a gyro for effect of the earth's rotation.

Because the earth is rotating toward the east, an observer on earth views a gyro as tipping its spin axis westward. To compensate for this apparent rotation, the gyro must be made to precess eastward at a rate equal to the apparent westward rotation. One method of correction is shown in the following illustration. You will remember that since a gyro will precess at an angle of 90 degrees from the force and in direction of the spin, a weight attached as shown will precess the gyro in the proper direction. Steps will be taken to assure that the weight, called the latitude correction weight, will always be oriented to north. The rate of precession you will recall, is proportional to the force and therefore may be controlled by moving the weight in or out along the correction arm. The rate of apparent rotation depends on the latitude and varies from zero at the poles to a maximum at the equator. The correction arm will be marked to indicate correct position of the weight for the latitude at which the gyro is located.



7. LATITUDE CORRECTION WEIGHT

CAUSES AND EFFECT OF MECHANICAL DRIFT AND ITS COMPENSATION

Because of mechanical drift, the line of direction of a gyro is not always in the direction in which it theoretically should point. The direction depends on its application. In the case of a stable element (used in some fire control systems), the spin axis should be vertical. Looking at it another way, the rotor should spin in a horizontal plane.

A directional error in a gyro is produced by random inaccuracies in the system caused by mechanical drift.

There are three general sources of mechanical drift:

1. UNBALANCE - A gyro often becomes dynamically unbalanced when operated at a speed or temperature other than that for which it was designed. Remember that the slower the speed of the gyro, the easier it is to precess. The static balance of a gyro may be upset because its center of gravity is not at the intersection of the three major axes. Some unbalance of both types will exist in any gyro since manufacturing processes cannot produce a perfectly balanced gyro.

2. BEARING FRICTION - Friction in the gimbal bearing results in loss of energy and incorrect gimbal positions. Friction in the rotor bearings causes mechanical drift only if the friction is not symmetrical. An even amount of friction all around in a rotor bearing results only in a change of the rate of rotation.

3. INERTIA OF GIMBALS - Energy is lost whenever a gimbal rotates because of the inertia of the gimbal. The greater the mass of the gimbal, the greater the drift from this source.

The complete elimination of mechanical drift in gyros appears to be an impossibility. However, by proper design, it has been kept to a minimum. You may be wondering why an FT cares about design. The reason for listing some of the sources of drift was to impress upon you that gyros do have sources of error built into them. Furthermore, when you work on a gyro don't unintentionally increase these errors. An easy way to do this would be to allow dirt, a piece of solder, or any other foreign matter to get into a gimbal bearing. Excessive lubrication is another source of error.

To help a gyro find its desired position and compensate for mechanical drift, in order, to maintain that position, some type of erecting system will be used. Basically the gyro is made to precess in a direction to offset the tilt due to mechanical drift. The effect of gravity on some type of device is used to create the desired force.

REVIEW AND SUMMARY

Any rapidly spinning object will exhibit all the properties of a gyro.

Gyros exhibit two basic properties, rigidity and precession. Rigidity is the tendency for the gyro spin axis to remain in a fixed direction in space if no force is applied to disturb it. Precession is the tendency for the gyro spin axis to move at a right angle to any disturbing force.

The basic components of a gyro are rotor, inner gimbal, outer gimbal, and base or support.

The three axes of a gyro are spin axis, torque or servo axis, and tilt or precession axis.

Rotation of the earth causes an apparent rotation of the gyro spin axis, however, the spin axis actually remains rigid in space. When undesirable, this apparent rotation may be compensated for by causing the gyro to precess at a rate and a direction to offset the effect of earth's rotation.

All mechanical gyros are affected by mechanical drift that causes inherent errors for which compensation is usually made.

TOPIC 2: CLASSIFICATION AND MECHANICS OF GYROSCOPES

YOU ARE NOW GOING TO LEARN:

1. Gyro classifications.
2. Methods of spinning the gyro wheel.
3. Methods of measuring gyro movement.
4. Methods of positioning a gyro.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Gyro classifications.
    a. Degree-of-freedom.
    b. Rate gyro.
    c. Integrating gyro.
2. Methods of spinning the gyro wheel.
3. Methods of measuring gyro movement.
    a. E-transformer.
    b. Microsyn.
4. Methods of positioning a gyro.
    a. Erection systems.
    b. Restraining.
    c. Damping.
    d. Caging.
    e. Torquing.
5. Review and summary.

INFORMATION AND DISCUSSION:

GYRO CLASSIFICATIONS

There are several ways to classify a gyro. One means of classification is in terms of the number of axes about which the gyro is free to precess. Another means of classification of gyros is by the use or function of the gyro. The naming or classification of various gyros will depend to some extent upon the source of information you are using. The material presented here will attempt to point out the various classifications used and how some of the names may be interchanged.

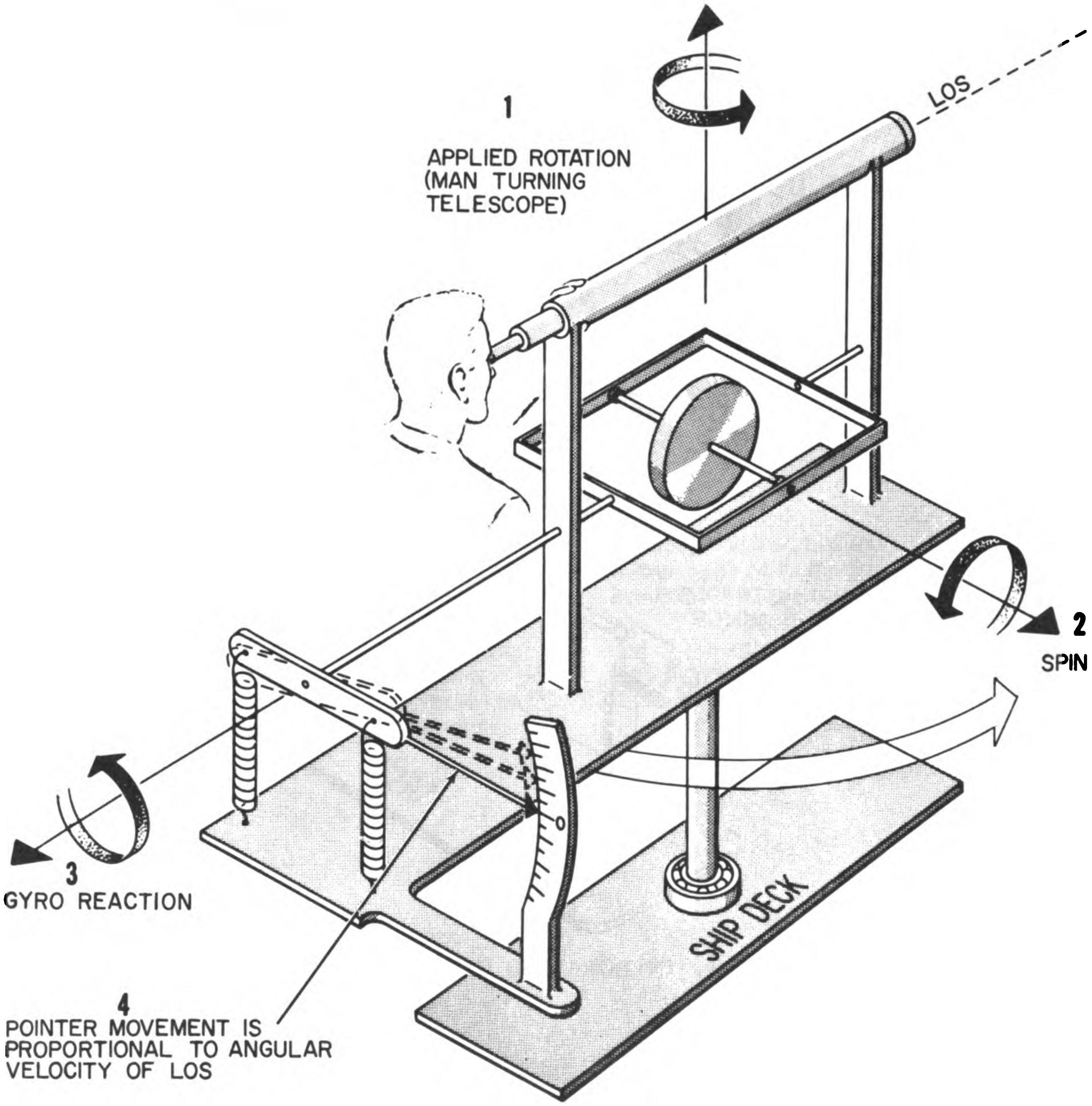
Degree-of-freedom is a common way to classify gyros. In determining the degree-of-freedom, the freedom to spin about the spin axis is not counted. There are two-degree-of-freedom and single-degree-of-freedom gyros. You may read about or hear about "three-degree-of-freedom gyros", but do not let this term confuse you. It can only result from incorrectly counting the spin axis as a degree-of-freedom; or the use of more than one rotor such as combining two different two-degree-of-freedom gyros into a system which should be called a three-degree-of-freedom gyro SYSTEM rather than a three-degree-of-freedom gyro. Also, you must not confuse the term "degree-of-freedom" with an angular value such as degrees of a circle. The term as it is applied to gyros is an indication of the number of axes about which the rotor is free to precess.

A two-degree-of-freedom gyro is mounted such that the base support is free to rotate about both the inner and outer gimbals without disturbing the stabilized reference line (spin axis). The universally mounted gyro is an example. This type of gyro is commonly called a "free gyro". In some instances a free gyro may have its spin axis oriented perpendicular to the earth's surface and maintained in this position by some type of erection system. Under these conditions the gyro may be called a "vertical gyro". The Mk 6 Stable Element which will be discussed later is one example. In another application, the free gyro may have its spin axis oriented and maintained in a horizontal plane. Under these conditions the gyro may be called a "directional gyro". The ship's gyrocompass is an example.

A single-degree-of-freedom gyro is mounted such that the base support is free to rotate about only one gimbal axis without disturbing the spin axis.

Two special single-degree-of-freedom gyros are the Rate gyro and the Integrating gyro. These gyros are often called "constrained" or "restrained" gyros because the freedom of precession is controlled by some mechanical or electrical system. By definition, when rotation is applied and gyro reaction measured, the gyro is a Rate gyro. Also when torque is applied and the precession measured, the gyro is an Integrating gyro.

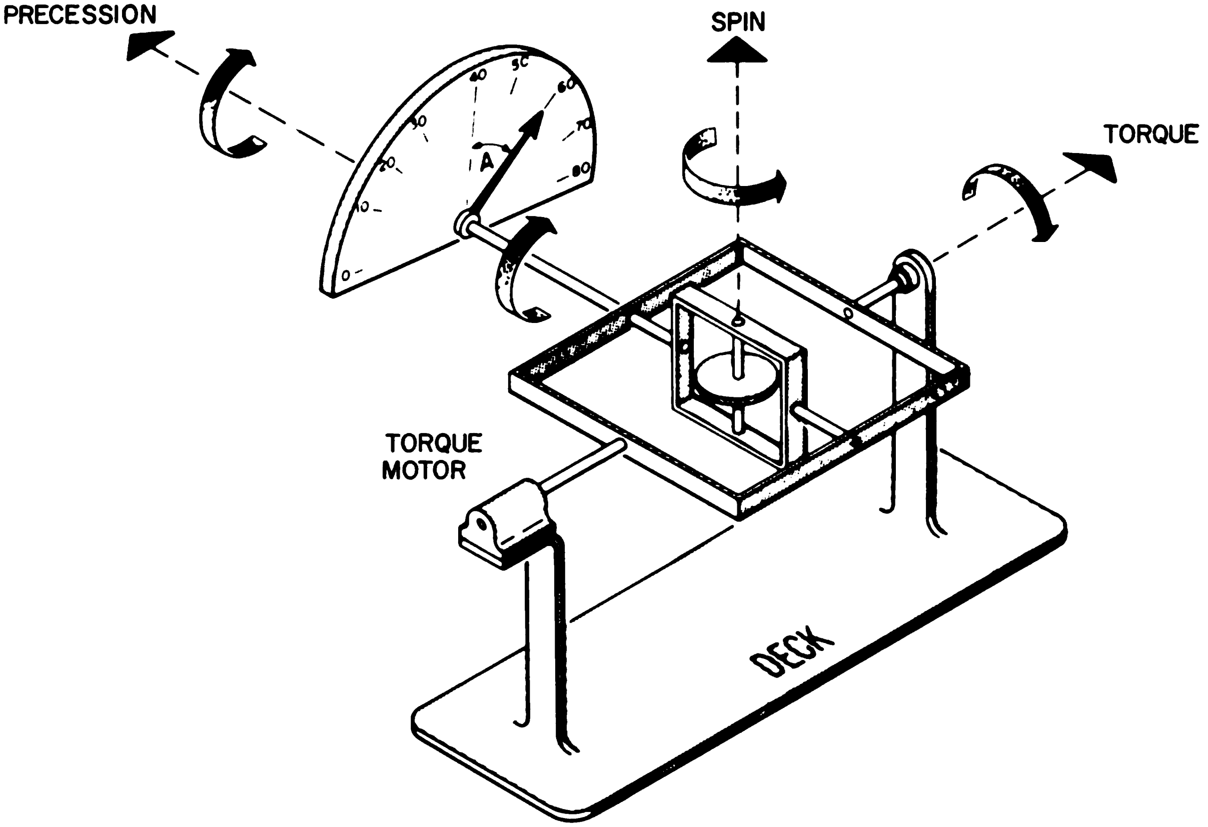
The illustration below shows the principle of a rate gyro used to measure the angular velocity of the line-of-sight. A telescope, trained on the target, supplies the applied rotation; springs supply the restraint, and measure the gyro reaction.


1
APPLIED ROTATION (MAN TURNING TELESCOPE)
LOS
2
SPIN
3
GYRO REACTION
4
POINTER MOVEMENT IS PROPORTIONAL TO ANGULAR VELOCITY OF LOS
SHIP DECK

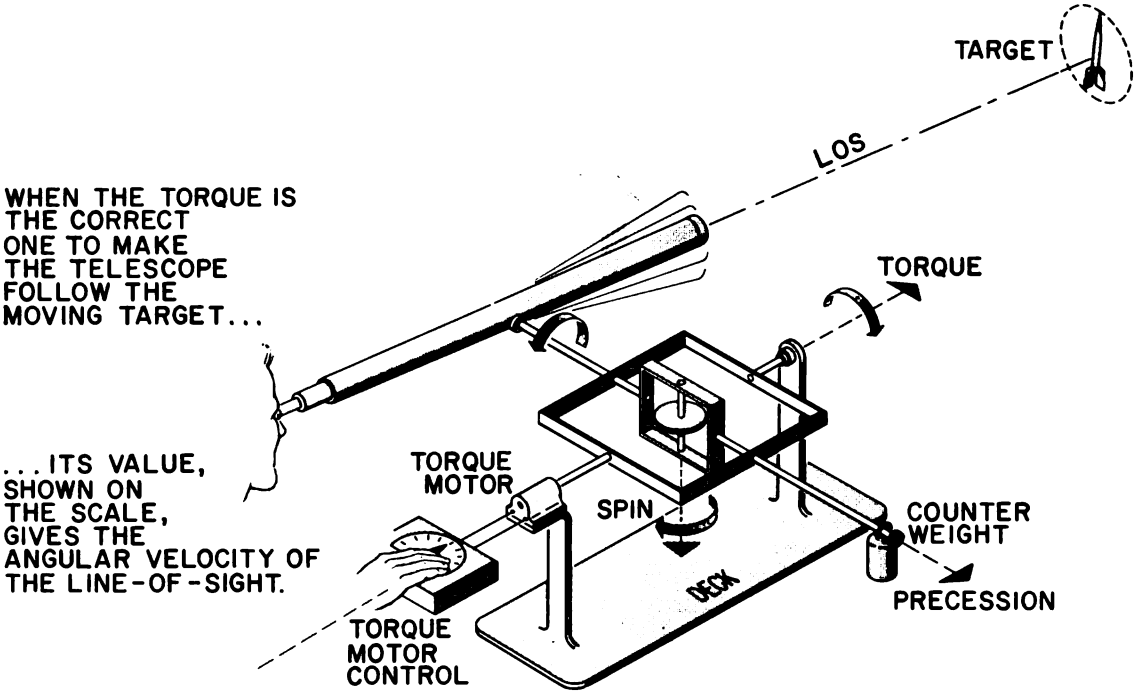
8. RATE GYRO

The illustration below shows the principle of an integrating gyro used for direct integration. A torque proportional to some quantity whose time integral is desired, is applied to the gyro, causing it to precess. Since rate of precession is proportional to torque, the angle precessed through is proportional to the time integral of the applied torque.

To understand the above statement, you must first of all know what a time integral is. Integration is the mathematical term for summing. For instance, if you were to sum or add up small bits of angular velocity over a period of time, you would obtain the total angle traveled. The total angle is the time integral of the angular velocity. Now if the applied torque were made proportional to the angular velocity, you can see that the angle precessed through would be the time integral of the angular velocity.



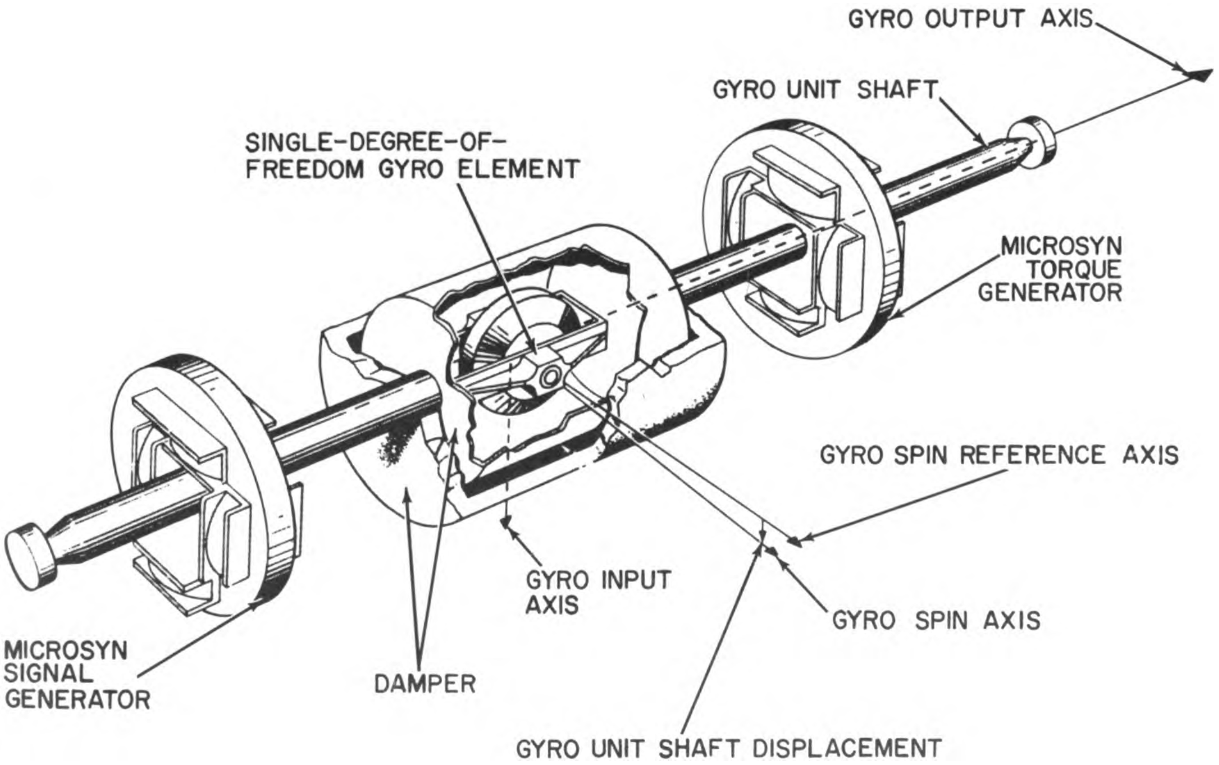
9. INTEGRATING GYRO


TARGET
LOS
WHEN THE TORQUE IS THE CORRECT ONE TO MAKE THE TELESCOPE FOLLOW THE MOVING TARGET...
TORQUE
...ITS VALUE, SHOWN ON THE SCALE, GIVES THE ANGULAR VELOCITY OF THE LINE-OF-SIGHT.
TORQUE MOTOR
SPIN
COUNTER WEIGHT
DECK
PRECESSION
TORQUE MOTOR CONTROL

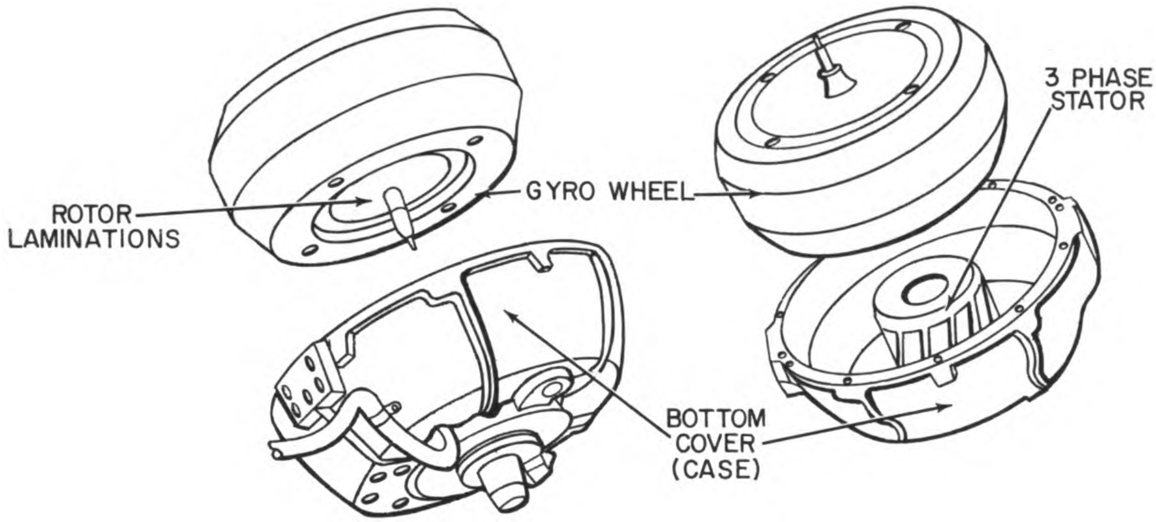
10. INTEGRATING GYRO USED TO MEASURE RATE

An integrating gyro can be made to measure angular velocity, but not by direct differentiation (as with a rate gyro), but by an indirect method. The illustration above shows this method. Torque is the applied value but it is also measured. A telescope is attached to a gyro which is oriented so that when the gyro is caused to precess, the telescope will follow the line-of-sight. The torque applied to the gyro is varied until the crosshairs of the telescope stay on the target. The magnitude of the torque is a measure of the rate of precession and therefore a measure of the target's angular velocity. An integrating gyro used in this manner is often called a precession rate output gyro.

A type of integrating gyro commonly used in fire control equipment is the floated gyro unit. This unit is also called a draper gyro or more commonly the HIG (hermetically sealed integrating gyro). The HIG designation is completed by a number between 3 and 7. This number is associated with angular momentum of the rotor, which determines the rigidity of the gyro. Below is a cutaway view of a HIG. The principal components of the gyro are: the rotor, gimbal, signal generator, torque generator, and the viscous damping fluid. The gyro rotor and stator are in a sealed cylinder filled with a gas, usually helium. The gas serves to transfer the heat generated by the stator windings to the surface of the cylinder. The closed metal cylinder acts as the inner gimbal and is mounted on precision bearings. The space between the gimbal and the case is filled with a viscous damping fluid of high specific gravity. Because of the high specific gravity of the fluid, it serves to float the inner gimbal and its shaft. This reduces the gimbal bearing friction and mechanical drift. The damping fluid in the HIG also performs another very important function. The HIG contains no restraining springs; therefore when a torque is developed about the input axis, the only thing resisting the rotation of the gimbal is the damping fluid. The resistance to the gimbal rotation depends directly upon the viscosity of the damping fluid and the velocity with which the gimbal rotates. The angular velocity of gimbal rotation is a function of the torque caused by the angular velocity about the input axis. Example: The viscosity of the damping fluid can be selected such that the velocity of the gimbal rotation about the output axis is the same as the angular velocity, which created the torque about the input axis. In this manner the damping fluid provides an integrating function such that the gimbal rotation about the output axis is a measure of rotation about the input axis.


GYRO OUTPUT AXIS
GYRO UNIT SHAFT
SINGLE-DEGREE-OF-FREEDOM GYRO ELEMENT
MICROSYN TORQUE GENERATOR
GYRO SPIN REFERENCE AXIS
GYRO INPUT AXIS
GYRO SPIN AXIS
MICROSYN SIGNAL GENERATOR
DAMPER
GYRO UNIT SHAFT DISPLACEMENT

11. CUTAWAY VIEW OF HIG



12. STABLE VERTICAL GYRO WHEEL

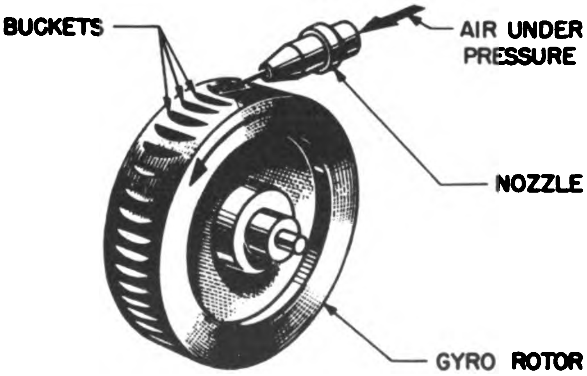
By this time you will realize that gyros may be referred to in many ways. Very little standardization exists in the gyro field. There is no standard vertical, directional, rate, or integrating gyro. The size, spinning force, type of pickoffs used, and other factors differ depending on the particular manufacturer or application. You should not be concerned with the name however, but rather with their function and how they operate. You have learned some ways to classify a gyro; you will now study some of the mechanics of gyros.

METHODS OF SPINNING THE GYRO WHEEL

Various means can be used to bring a gyro up to speed. The wheel may be driven by an electric motor or a jet of air or some other gas. In some missile applications, where the rotor must reach full speed in a very short time and only be needed for a few minutes, a clockspring or explosive charge may be used as the driving force.

When an electric motor is used as the driving force, the motor is usually built differently than other motors which you have studied. For gyro application, the rotor is designed to rotate around the outside of the stator winding. You will remember that the weight of the gyro wheel and the concentration of the weight near the outer rim are two of the factors which determine the rigidity of the gyro. By making the rotor the outside of the motor, the greatest inertia and hence the greatest rigidity may be obtained for a given motor weight. The illustration above shows the wheel construction for an electrically driven gyro.

When air or some other gas is used as the driving force, the rotor is built with turbine buckets. The air that is forced from a nozzle into the buckets drives the rotor. The illustration below shows the rotor construction of an air driven gyro.



13. GUNSIGHT GYRO ROTOR

METHODS OF MEASURING GYRO MOVEMENT

Unless the gyro is being used as a brute force device, the gyro movement must be measured before the gyro is useful. A brute force gyro is one which is directly fastened or geared to a system to position some device, such as a gunsight mirror, as the gyro moves. In most of the gyros you will work with, the movement of the gyro is measured by a pickoff device and the output of the pickoff is used in some manner. Many different types of pickoff devices may be used. The type of pickoff used depends upon several factors. The accuracy required, sensitivity, size, reaction torque which can be tolerated, and cost are some of the factors which determine the type of pickoff.

Potentiometers, variable transformers, and photoelectric units are some of the devices which may be used as pickoffs.

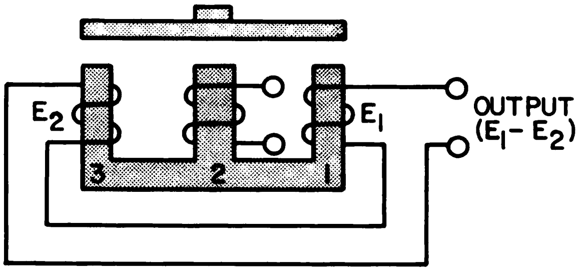
Potentiometers have high torque levels which will cause drift of the gyro, however, they can be made to handle fairly high power and are generally inexpensive.

Variable transformers include several devices which you have already studied. Some of these devices are synchros, resolvers, E-transformers, and the microsyn.

You will remember that synchros are electromechanical devices which put out an electrical signal depending upon the rotor position with respect to the stator. Synchros can be made which are fairly accurate, exert very little torque, and are comparatively inexpensive.

Resolvers are also electromechanical devices which function as variable transformers. The stator windings will act as the primary and the rotor windings as the secondary. There are two stator windings and two rotor windings electrically isolated and displaced by 90 degrees. The outputs taken from the rotor windings will vary as the sine and cosine functions of the angular displacement of the rotor. Accuracy, torque, and cost of a resolver are similar to the synchro.

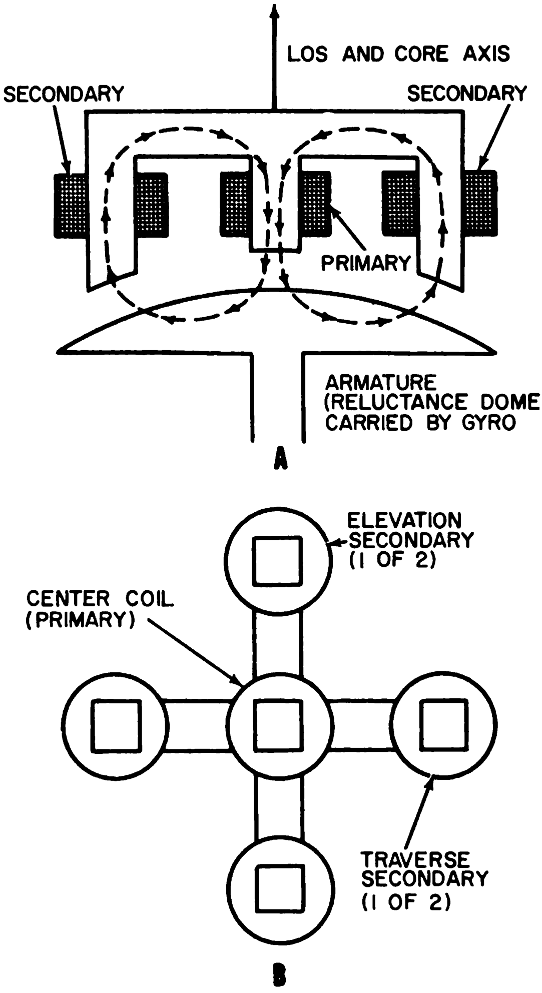
E-transformers are another type of pickoff device which operate as variable transformers. A basic E-transformer is shown below.



14. BASIC E-TRANSFORMER

An AC voltage is applied to the primary coil on the center pole (2). The two secondary coils (1 and 3) are wound in series opposition. When the armature is located in the center, as shown, equal voltages are induced in the secondary coils and there is no output. If the armature is moved to one side, the reluctance between the poles will be different (the electromagnetic coupling will change) therefore the voltage induced in the secondary coils will be different. The output will be the difference in the induced voltages. The output will provide a sense of direction of movement since the output can either be in phase or 180 degrees out of phase with the applied AC. A variation of the E-transformer, called the crossed E-transformer is shown on the facing page. This arrangement is frequenctly used in gyro systems to measure movement in two planes. The crossed E-transformer has two E type transformers placed at right angles and the armature is dome shaped.

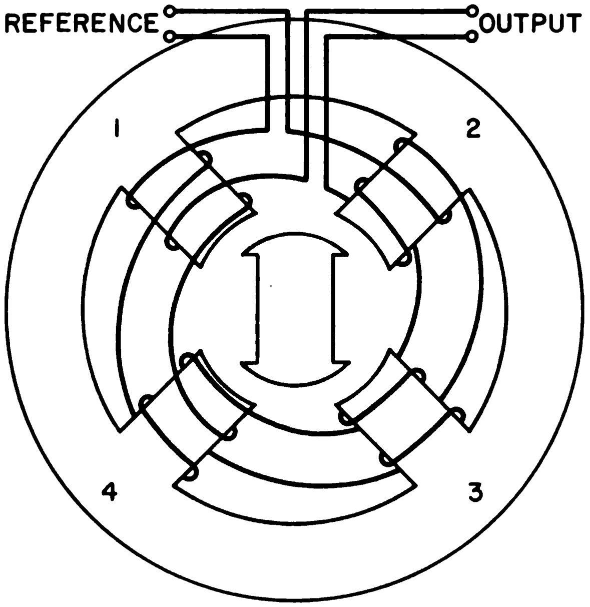
The microsyn is another electromechanical device which may be used as a pickoff. When used as a pickoff, it may be called a microsyn transmitter or signal generator. The microsyn may also be used as a torquer. In this application the device may be called a torque motor, torque generator, or a microsyn receiver.


LOS AND CORE AXIS
SECONDARY
SECONDARY
PRIMARY
ARMATURE (RELUCTANCE DOME) CARRIED BY GYRO
A
ELEVATION SECONDARY (1 OF 2)
CENTER COIL (PRIMARY)
TRAVERSE SECONDARY (1 OF 2)
B

15. CROSSED E-TRANSFORMER

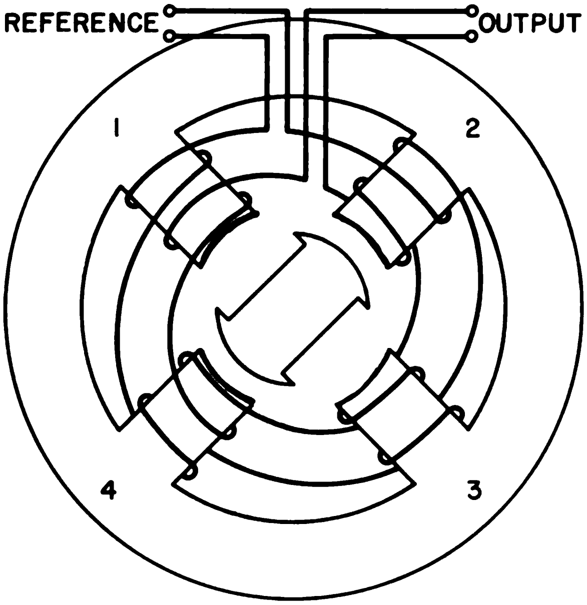
Either unit consists of a two pole rotor and a four pole stator. The four poles are displaced 90 degrees from each other. A primary coil and a secondary coil are wound on each stator pole. The rotor has no windings and serves only to change the reluctance of the magnetic paths between the stator poles. The rotor is mounted on ball bearings and because it has no winding, no electrical or other external connections are necessary, and therefore exhibits low torque when used as a pickoff.

In a microsyn transmitter, the four primary coils are connected in series and are excited by a reference voltage (usually 400 cycle). The coils are wound so that the flux in pole 1 aids the flux in pole 4, and the flux in pole 2 aids the flux in pole 3. When the rotor is attached to the output shaft of a gyro, it will be displaced as the gyro precesses. When the microsyn rotor is at the zero or null position as shown below, equal amounts of rotor iron are under each of the pole faces. In this position, the pole 1 - pole 4 flux through the rotor equals the pole 2 - pole 3 flux through the rotor. Equal voltages are now induced in the secondary coils. These four secondary coils are also connected in series. The voltage induced in the pole 1 secondary aids the voltage induced in the pole 3 secondary. The voltage induced in the pole 2 secondary aids the voltage induced in the pole 4 secondary. The combined voltages of poles 1 and 3 secondaries oppose the combined voltages of poles 2 and 4 secondaries. When the rotor is at the zero position, these two pairs of voltage are equal and there is no output.



16. MICROSYN TRANSMITTER AT ZERO POSITION

When the rotor of the microsyn is turned to the position shown below, the amount of rotor iron under poles 2 and 4 exceeds the amount of rotor iron under poles 1 and 3. The total voltage induced in the secondary coils of poles 2 and 4 now exceeds that induced in the secondary coils of poles 1 and 3. The phase of the output is now that of the voltage induced in coils 2 and 4 and the amplitude is the difference between the voltage induced in 2 and 4 and the voltage induced in 1 and 3. If the rotor is aligned in the opposite direction, the phase of the output will be reversed.

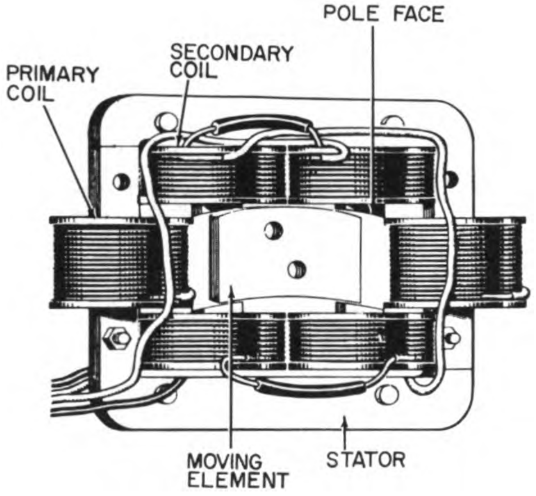


17. MICROSYN TRANSMITTER AT MAXIMUM OUTPUT POSITION

The following illustration shows another type of pickoff transformer. You may find still other types of transformers used as gyro pickoffs, however, they will all function in basically the same way.

METHODS OF POSITIONING A GYRO

In this section you will study various ways of affecting the position of the gyro. The ways of affecting the position of a gyro may be one or more of the following methods:



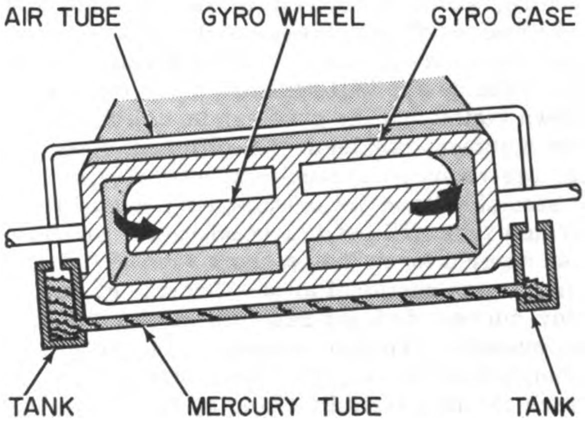
18. PICKOFF TRANSFORMER

1. Erection systems.
2. Restraining.
3. Damping.
4. Caging.
5. Torquing.

ERECTION SYSTEMS - You will remember that a gyro has the property of rigidity. To make use of this property it is often desired to orient the spin axis in a particular direction. You will also remember that the earth's rotation caused an apparent drift and that other random drifts were caused by such things as unbalance and friction. You learned how a latitude correction weight could be used to compensate for the effect of earth's rotation. In the discussion which follows, you will learn about some of the ways in which the gyro is caused to orient to and retain a specific reference. This reference may be in relation to the earth, or to a particular axis of a missile. The function of the gyro will determine the desired direction of reference. In this discussion we will consider gyros oriented perpendicular to the earth's surface.

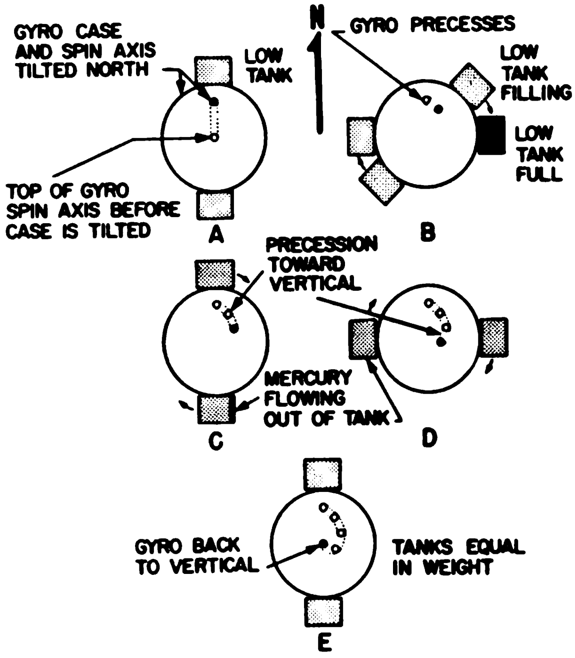
The basic requirements for any erection system are a means of causing the gyro to position to the desired reference when the rotor is first started spinning, a means of detecting any movement away from the reference, and a means of applying torque to cause the gyro to precess back to the reference.

One common type of erection system is the mercury system. As shown below, this system consists of two tanks of mercury fastened to opposite sides of the gyro case and connected by a small mercury tube. A small air tube is also connected between the tanks to prevent the forming of a vacuum. If the gyro tilts away from the reference, the mercury will flow from one tank to the other. The added weight will provide a torque which causes the gyro to precess. At this point if you apply the rule for precession, you will see that the precession would be 90 degrees away from the desired direction.



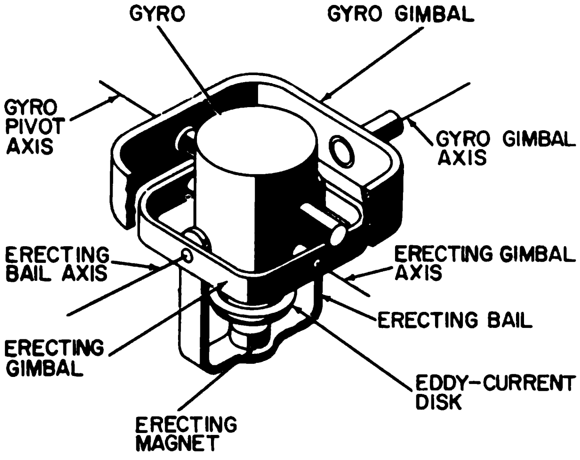
19. MERCURY SYSTEM

To overcome this difficulty, the point of applying torque must be moved. The torque point is moved by causing the outer gimbal to slowly and continuously rotate in the proper direction. With a small mercury tube, it will take some length of time for the mercury to flow from one tank to the other. By proper selection of gimbal rotation speed, the tanks may be displaced 90 degrees during the flow of the mercury. The torque will now be applied at a point which causes the gyro to precess in the proper direction. Below is an illustration showing the effect of gimbal rotation.


GYRO CASE AND SPIN AXIS TILTED NORTH
LOW TANK
N
GYRO PRECESSES
LOW TANK FILLING
LOW TANK FULL
TOP OF GYRO SPIN AXIS BEFORE CASE IS TILTED
A
B
PRECESSION TOWARD VERTICAL
MERCURY FLOWING OUT OF TANK
C
D
GYRO BACK TO VERTICAL
TANKS EQUAL IN WEIGHT
E

20. EFFECT OF GIMBAL ROTATION

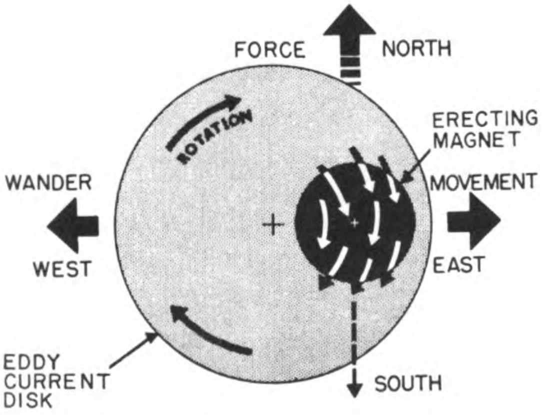
Another type of erection system is shown below. This type of system is known as a magnetic erection system.



21. MAGNETIC ERECTION SYSTEM

In the magnetic erection system a magnet, bail, and gimbal are suspended from the gyro on an axis below the gyro pivot axis. The magnet is free to swing about both the erection bail and gimbal axes and therefore acts like a pendulum which tends to remain perpendicular to the earth's surface. The eddy-current disk is mounted on the gyro shaft and spins with the gyro rotor. You will remember that when a conductor is moved in a magnetic field, current is induced in the conductor. The current in the disk produces a magnetic field which opposes the movement. The torque created causes the gyro to precess back to its center position.

In the illustration below the gyro has tilted such that the disk mounted on the bottom of the gyro shaft has wandered to the west. The disk is moving south through the field so the force opposing the movement acts to the north. Applying the rules of precession, you will see that the disk will precess to the east.



22. OPERATION OF MAGNET

An E-transformer pickoff, pendulum arrangement may also be used in an erection system. For this application the moving element of the transformer is a pendulum. Just as discussed in pickoffs, any displacement of the moving element causes an electrical output. This output may then be applied to some type of torquer to precess the gyro.

Many other types of erection systems may be found; but all will have basically the same function - to maintain the gyro reference position.

RESTRAINING - For a gyro to be used to measure rate or angular movement, it is necessary that the gyro precession be controlled or restrained. You will remember that the rate of precession of a gyro is proportional to the applied torque and that a gyro will continue to precess as long as the torque is applied or until the precessional torque is balanced by a restraining force.

In a rate gyro for example, rotation is applied and the gyro will precess until the precessional force is balanced by the restraining force. The restraining torque is then measured and thus the rate of the applied rotation is determined. In most cases the torque is not measured directly but the gyro is calibrated such that the angular displacement measured by pickoffs is a function of the restraining torque.

Many means can be used to provide the restraint. Springs, torsion wires, torque motors, and eddy-current disks are some of the items used as restraining devices. In each device used, the amount of torque with which the device will restrain the gyro is a known factor and the gyro can be calibrated. For instance, you know that different size springs require different amounts of force to stretch or compress the spring and a long torsion wire will bend or twist easier or with less applied force than a short wire of the same cross sectional area. The use of an eddy-current disk for restraint is similar to the magnetic erection system. The force is a function of the magnetic field strength, which can be varied by changing the excitation voltage of the magnet.

Other devices may be used to restrain a gyro but in each application the relation between restraining torque and angular precession of the gyro will be known or controlled.

DAMPING - In the use of a gyro to measure angular rate or amount of rotation, it is desired to obtain smooth output data. Spurious tracking errors caused by a director operator or sudden changes in the flight attitude of a missile due to random air currents will cause torques to precess the gyro. If the gyro is allowed to instantaneously follow these torques, false lead angles and rates will be developed. To compensate for these effects, a damping system is used. The damping system will slow the response and cause the gyro to precess according to an average rate or torque rather than following the individual peaks.

Viscous damping may be used in several different ways. Damping disks rotating in a fluid filled case may be attached to the gyro output axis or the gyro may be caused to precess against the action of a dashpot. In another type of construction the outer gimbal, which is a closed cylinder, may rotate in a fluid filled outer case. The amount of damping of a viscous damper is sensitive to temperature variations and therefore this type of damper requires a heater and thermostat to maintain constant viscosity. A number of mechanical means have been devised to reduce the damping variation with temperature. These are all aimed at eliminating the heater and thermostat. If the gap separating the moving element of the damper from the case can be decreased as the viscosity of the fluid decreases (fluid becomes thinner or increases in volume), the variation in damping will be less.

One method of construction is to provide a bellows arrangement for the outer case which will vary the gap as the fluid is heated or cooled. Another method of changing the gap uses the different expansion characteristics of materials. The outer case and gimbal case are constructed of different materials which expand or shrink by different amounts to vary the gap as the fluid is heated or cooled.

The use of eddy-current disks is another means of providing damping. The principles of eddy-current disks were studied earlier.

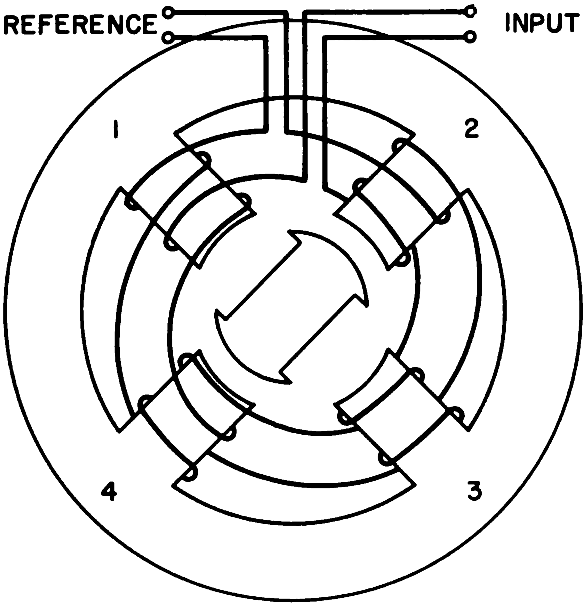
Other devices may be used and any device which slows the gyro response so the gyro is not oversensitive to spurious peak movements can be considered as a damper. An example is found in the mercury erection system. The time required for the mercury to flow between tanks actually delays the gyro reaction. The gyro will be stabilized to compensate for average values of displacement but will not respond to instantaneous peaks.

CAGING - The term "to cage a gyro", means to mechanically or electrically lock the gyro gimbals in some particular position with respect to the base support. It may be desirable to cage a gyro for several reasons. Gyros may be caged during shipment or periods of unuse to prevent damage to the unit. Another reason for caging is to lock missile gyros during launch and booster flight and then uncage and apply power so the gyros will be properly oriented during the guidance phase.

Caging may be accomplished by electrically applied torques or by mechanical latches or clamping devices actuated by air or electrical systems. In some cases the only caging device may be an iron strap bolted to the gyro when power is removed or the gyro is to be shipped.

TORQUING - By this time you should be able to think of many reasons why it is necessary or desirable to apply torque to a gyro. You have seen how a weight was used to apply torque to compensate for the earth's rotation. Weights mounted on lever arms will frequently be used to apply torque to a gyro. Various electrical torquers will also be used to torque a gyro. Solenoids, induction motors, and microsyns are some of the common electrical torquers. All electrical torquers have two characteristics in common. The units are capable of producing torque in two directions around the null (the direction depends on the error signal); and there is no mechanical connection between the torquing device and the torqued member. A mechanical connection would have friction which would cause random drift. All three of the electrical torquers mentioned make use of electromagnetic principles.

The solenoid torquer consists of a pair of solenoids acting on an iron armature. The armature provides a lever to apply torque and is moved by applying voltage to one of the two solenoids, depending on the required direction of torque.



23. MICROSYN RECEIVER

One type of induction motor torquer is a conventional two-phase induction motor. The stator is mounted on the gimbal and the rotor on the gimbal axis. The AC applied to the stator sets up a rotating magnetic field which induces current in the rotor. The magnetic field caused by the rotor current interacts with the rotating stator field and causes the rotor to follow. As the rotor moves it applies torque to the gyro.

The microsyn is another device commonly used as a torquer. You were introduced to the microsyn earlier as a pickoff device. When the microsyn is used as a receiver (torquer), the rotor is attached to the input shaft of the gyro. Torque is applied as the rotor moves. The illustration above shows a microsyn which may be used as a torquer. Two voltages must be applied to the stator when the microsyn is used as a torquer. One of these voltages may be a reference voltage or a second input if two different control signals are used to torque the gyro. The phase relationship between the inputs will cause a stronger magnetic field to exist between either poles 1 and 3 or 2 and 4. The amplitude of the signals will determine the strength of the fields. The rotor will try to align itself with the stronger field and thus exert torque on the gyro.

REVIEW AND SUMMARY

Gyros may be classified in several ways, however one of the most common is "degree-of-freedom". This refers to the number of axes about which the gyro is free to precess. There are two-degree-of-freedom and single-degree-of-freedom gyros. An example of a two-degree-of-freedom gyro is the gyro used in the Stable Element Mk 6. Two special single-degree-of-freedom gyros are the rate gyro and the integrating gyro.

Before the gyro can be used in fire control, the wheel must be caused to spin and a means provided for measuring the gyro precession. Electrically driven and air driven gyros are those most commonly used in fire control. Microsyns, E-transformers, and other devices operating as variable transformers are common pickoff devices used for measuring gyro precession.

It is sometimes necessary to position the gyro. This may be done in order to orient the spin axis to a particular reference. In the case of a stable element, the spin axis is oriented to the vertical by some type of erection system. It may also be necessary to cause a gyro to precess in a particular direction and to control and measure the precession. Various means may be used to torque or restrain the gyro precession.

TOPIC 3: APPLICATIONS

YOU ARE NOW GOING TO LEARN:

1. How the Mk 6 Stable Element utilizes gyroscopic principles.
2. How the Mk 16 Stable Element utilizes gyroscopic principles.
3. How Radar Set AN/SPG 55-B utilizes gyroscopic principles.
4. How Gunsight Mk 29 utilizes gyroscopic principles.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Function of Mk 6 Stable Element.
2. The sensitive element.
3. Spinning the gyro wheel.
4. Measuring gyro movement.
5. Positioning the gyro.
6. Function of Mk 16 Stable Element.
7. The sensitive element.
8. Spinning the gyro wheel.
9. Positioning the gyro and measuring gyro movement.
10. Purpose of AN/SPG 55-B automatic tracking circuit.
11. Gyro orientation.
12. Function of the gyros.
13. Motion error sensing.
14. Function of Mk 29 Gunsight.
15. The gyros.
16. Spinning the gyro wheels.
17. Measuring gyro movement.
18. Positioning the gyros.
19. Review and summary.

INFORMATION AND DISCUSSION:

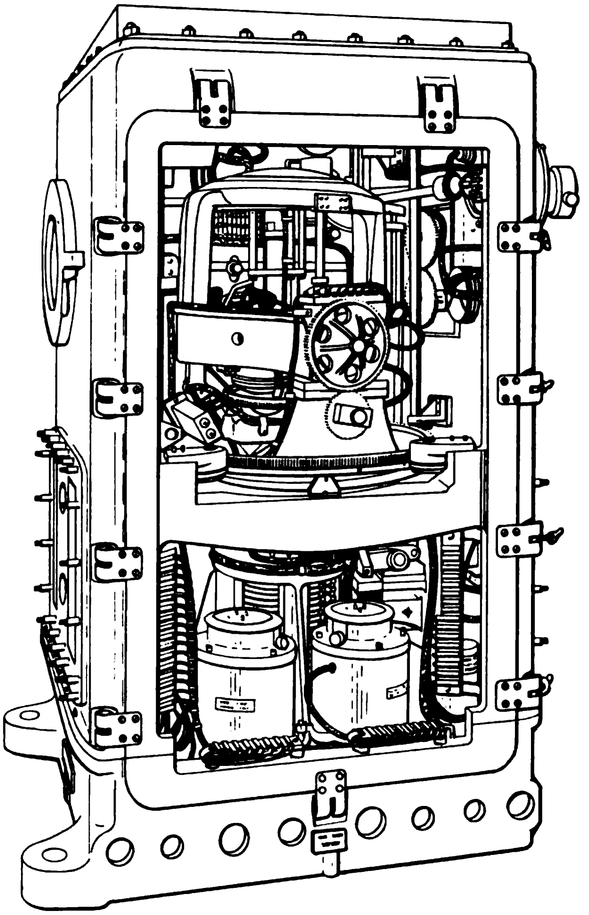
FUNCTION OF MK 6 STABLE ELEMENT

The Mk 6 Stable Element is a component of GFCS Mk 37. The GFCS Mk 37 is a shipboard mounted system primarily designed to direct the fire of 5"/38 and 5"/54 guns for surface, shore, or air targets. The system consists of the guns, director and radar, computer, and the stable element. The computer uses data from the radar, director, and stable element to solve the fire control problem. The purpose of the stable element (located in the plotting room next to the computer) is to measure the effects of ship's pitch and roll in and across the line-of-sight and transmit the quantities of level and cross-level to the computer to be used in solving the problem. Stable Element Mk 6 also transmits signals to the computer and to the director for stabilizing the line-of-sight. The illustration on the facing page shows the stable element with one cover removed.

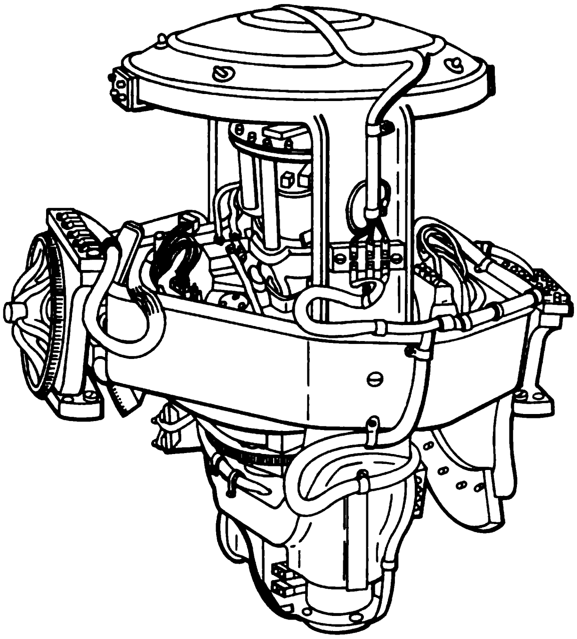
THE SENSITIVE ELEMENT

The sensitive element consists of a two-degree-of-freedom gyro which is in turn mounted within another pair of gimbals called the level and cross-level gimbals. The entire unit is mounted within a rotable casting which is positioned by director train signal. The illustration on facing page shows the sensitive element mounted in the level and cross-level gimbals.

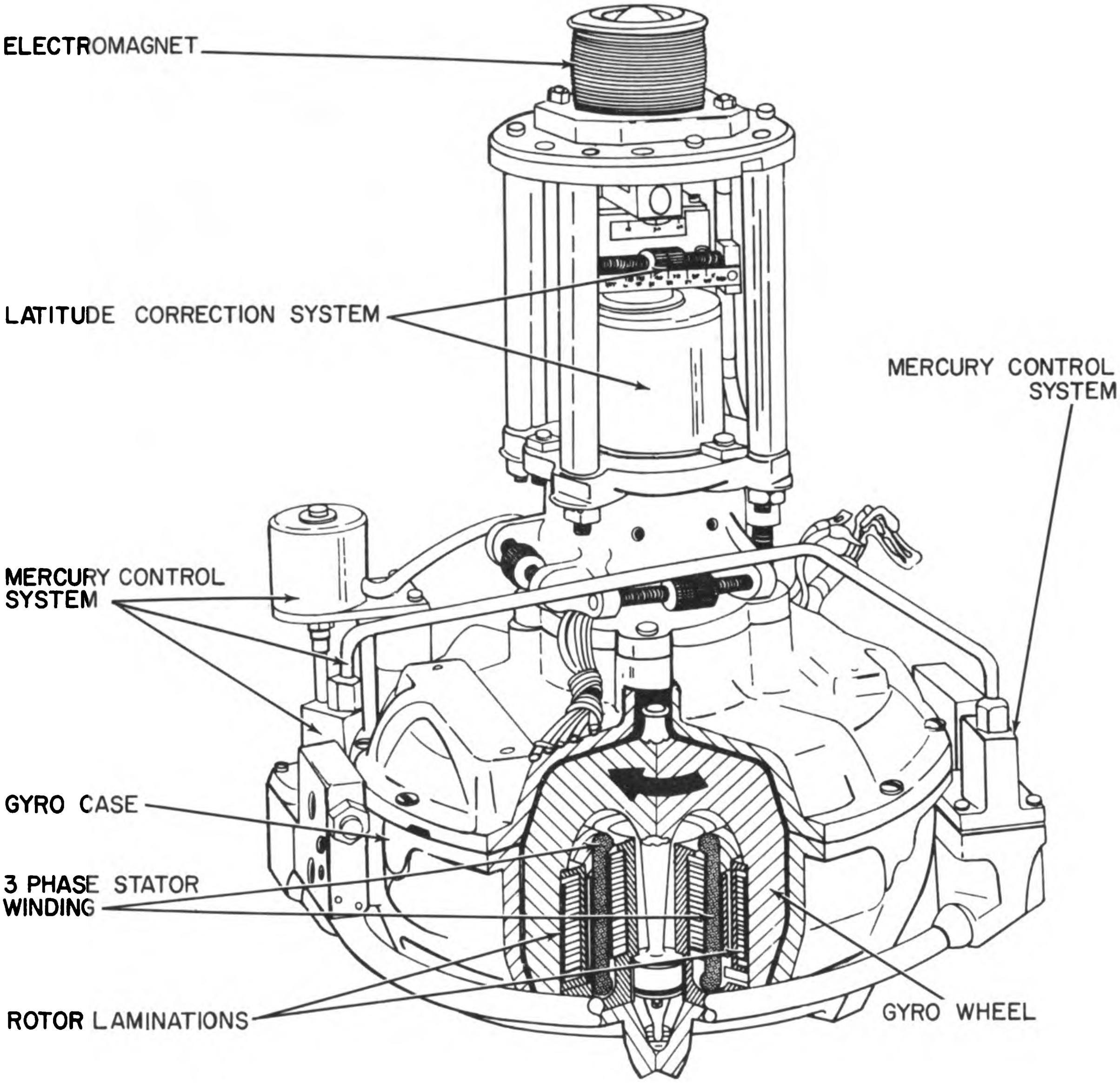
The gyro is an electrically driven, vertically stabilized free gyro, compensated for drift due to earth's rotation and random drifts. The gyro provides a true horizontal reference plane from which angles of pitch and roll of the ship can be measured by a follow-up or pickoff system.



24. STABLE ELEMENT MK 6



25. SENSITIVE ELEMENT MOUNTED IN LEVEL AND CROSS-LEVEL GIMBALS



26. GYRO ASSEMBLY

SPINNING THE GYRO WHEEL

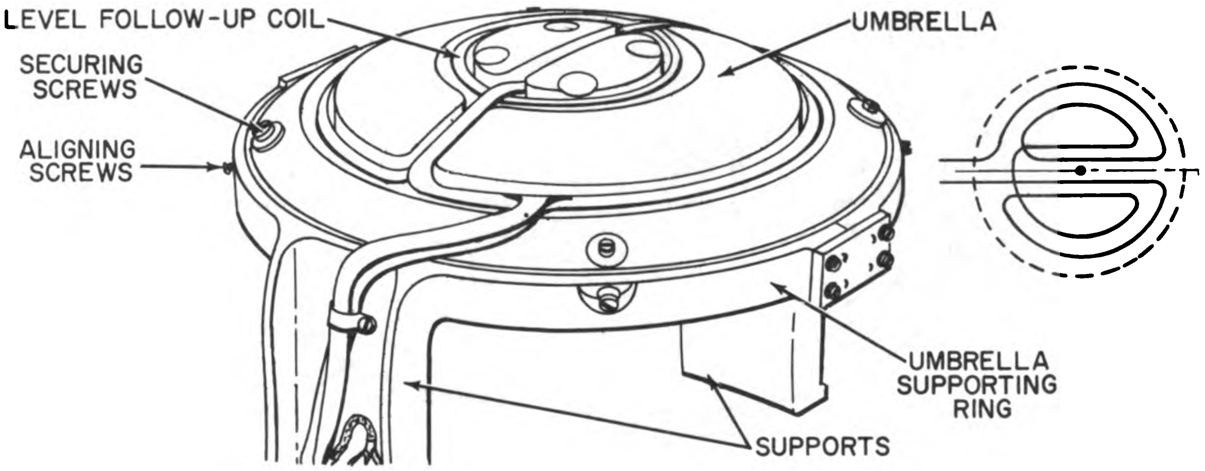
As shown in the illustration on the facing page, the gyro wheel is the rotor of an electric motor. The motor operates on 3 phase, 146 cps. power. The wheel spins at a nominal 8,500 rpm.

MEASURING GYRO MOVEMENT

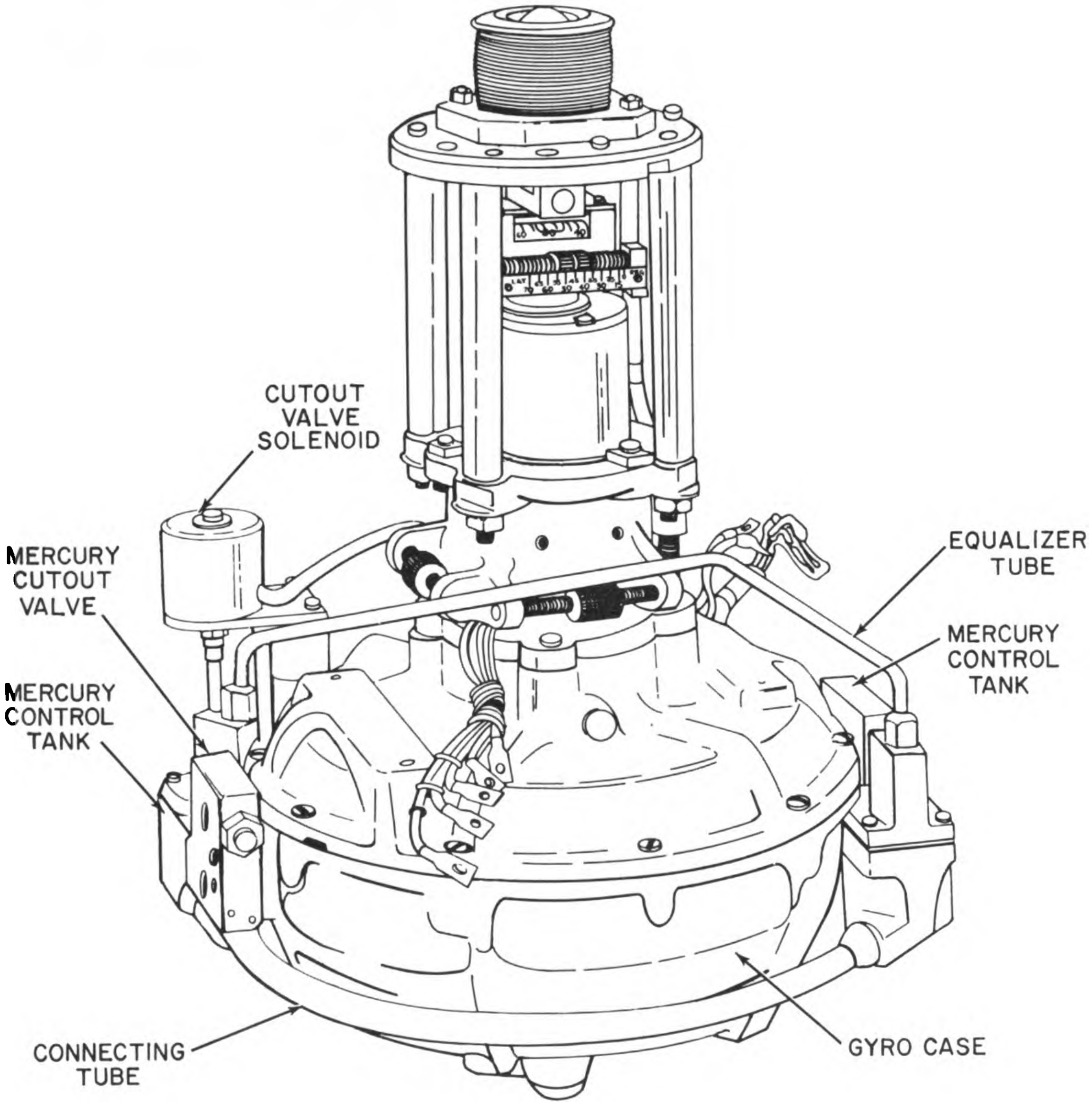
The pickoff device for the stable element consists of an AC electromagnet and two sets of follow-up coils. The magnet, seen in the illustration on facing page, is mounted above the latitude correction system and concentric with the stabilized spin axis of the gyro. The two coils, level and cross-level, are mounted one above the other on the umbrella. The illustration below shows one coil. The other coil is placed on the bottom of the umbrella. The fields of the two coils are at right angles to each other. The magnet is energized from the ship's 115 volt, 60 cycle supply and is capable of inducing voltages in the follow-up coils. The coils are wound so that the voltages induced in each half are equal and opposite if there is no displacement of the neutral point with respect to the magnet. The umbrella is supported by the inner gimbal and will be displaced by rolling or pitching of the ship. When the umbrella is displaced there will be an output from one or both of the coils. This output actuates a motor system to drive the gimbals to maintain the coils centered over the magnets. The positioning system also actuates mechanisms to transmit these very same motions (level and cross-level angles) to the computer and director.

POSITIONING THE GYRO

A mercury system is used for erection and compensation for random drift and a



27. UMBRELLA AND COIL



28. MERCURY ERECTION SYSTEM

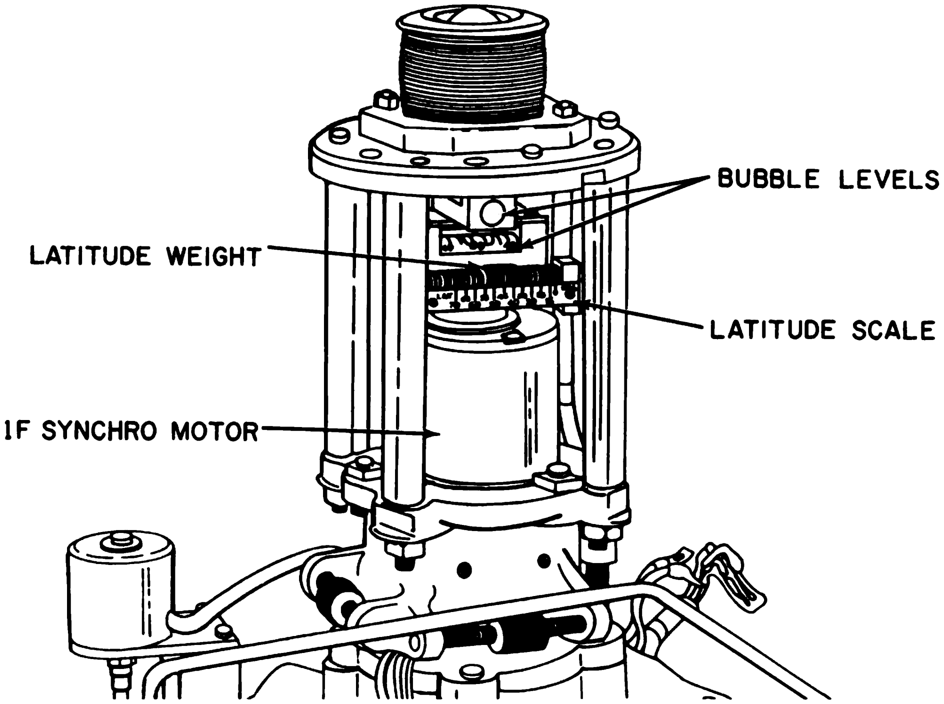
latitude weight is used to compensate for earth's rotation. No restraining, damping, or torquing devices are required and the only caging consists of an iron bar to secure the gyro element to the outer gimbal system during shipment or periods of unuse.

The illustration above shows the components of the mercury erection system. The mercury system is sensitive to any displacement of the gyro axis from the vertical, regardless of cause. Therefore, in starting the gyro, if the gyro axis is not vertical, the mercury system will bring it to the vertical and tend to maintain it in that position. As explained earlier, time is required for the mercury to flow from one tank to another, also the tanks must be rotated 90 degrees to apply torque at the proper point. In the Mk 6 Stable Element, the entire gyro and gimbal unit is rotated at approximately 18 rpm in the direction of spin.

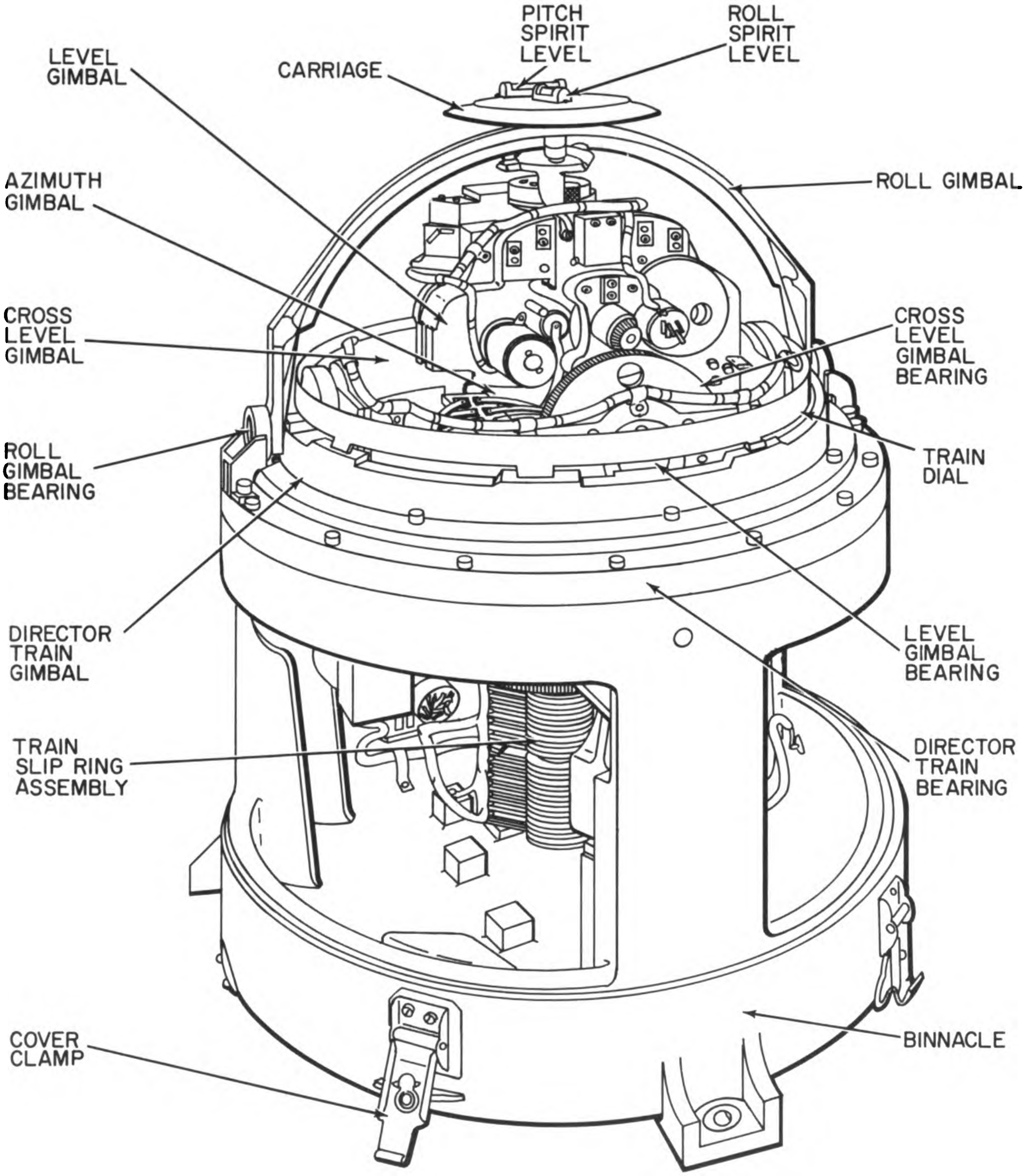
Rapid changes in ship's speed, high speed turns, or turns of small radius can cause surges in the mercury system which would tend to displace the gyro from the vertical rather than to right it. A cutoff valve is used to prevent the flow of the mercury under the conditions listed. The valve is actuated by a system which monitors ship's speed and course.

Effective operation of the mercury system depends upon a definite displacement of the gyro from the vertical. If the mercury system were acting alone, the gyro would deviate slightly from the vertical due to the earth's rotation. The latitude correction system shown below compensates for the earth's rotation. The latitude weight is positioned by hand, and must be set to the correct latitude of the ship's position.

To compensate for the earth's rotation, the latitude weight must cause an eastward precession. The gyro and gimbals are rotated at 18 rpm for the mercury system, also the entire mounting rotates with the training gear during changes in target bearing (director train). As you can see, a system must be used to keep the latitude weight properly oriented. The latitude correction system is mounted on the rotor shaft of a synchro which is mounted on the gyro case. The synchro is driven by two differential synchros in series. One of these differentials is driven by the training gear to compensate for director train and the other is driven by the same drive system which rotates the gyro and mountings at 18 rpm.



29. LATITUDE CORRECTION SYSTEM



30. STABLE ELEMENT MK 16

FUNCTION OF MK 16 STABLE ELEMENT

The stable element with the cover removed is shown in the illustration on the facing page. The Stable Element Mk 16 is a component of GFCS Mk 68. The GFCS Mk 68 is usually used to control the fire of the 5"/54 rapid fire, dual purpose guns aboard DDGs, DLGs, and the newest of the Navy's DDs. The GFCS Mk 68 can also control the 3"/50 gun batteries and in the future it is proposed that the system may be able to control missile batteries. The stable element is physically located in the plotting room of the ship along with the computer and the display components of the fire control radar. The purpose of the stable element is to measure the effects of the ship's roll and pitch. Stable Element Mk 16 uses a gyro as its sensitive element. Servo loops position the gimbals so that the gyro maintains its true vertical with reference to the earth's surface. Depending on the Mod of the Stable Element, either Level (Ei) and Cross-Level (Zd) or Roll (Zo) and Pitch (Eio) outputs are developed by measurement of gimbal positions. Ei and Zd are transmitted to gun fire control systems by using director train (Bd) to drive the director train gimbal. In missile systems the director train gimbal is clamped at zero, so the outputs are roll and pitch.

THE SENSITIVE ELEMENT

A phantom view of the sensitive element is shown in the illustration on the facing page. The sensitive element consists of a gyro wheel which is mounted inside of a sphere. The sphere is supported by a pair of torsion wires which are physically carried by a gimbal ring. The gimbal ring, in turn, is supported by another set of torsion wires which are physically supported by the flotation tank. The sphere containing the gyro wheel is filled with helium and hermetically sealed. The flotation tank is filled with a liquid of sufficient density to float the sphere at neutral buoyancy when the liquid is at operating temperature. This allows the torsion wires to fix the position of the sphere within the tank without carrying any load.

The gyro wheel is oriented and stabilized to the vertical. Electromagnets are fixed to the sphere and are in line with the spin axis of the gyro wheel. Pickup coils are mounted in the flotation tank in line with its vertical axis. The slightest displacement of the pickup coils from the axis of the wheel and magnets will cause an error voltage to appear. This voltage will be amplified and sent to servos which will reposition the pickup coils directly over the magnets, thereby, stabilizing the tank and relieving any tension on the torsion wires.

The sensitive element is supported in a complex of gimbals. These gimbals allow the sensitive element to move in any direction without unwanted physical restraint and yet can cause the gyro to precess to attain the desired attitude, that being the vertical. The following is a brief description of the five gimbals surrounding the sensitive element:

1. The sensitive element is supported by the azimuth gimbal whose axis is in the vertical while its reference is true north and south.

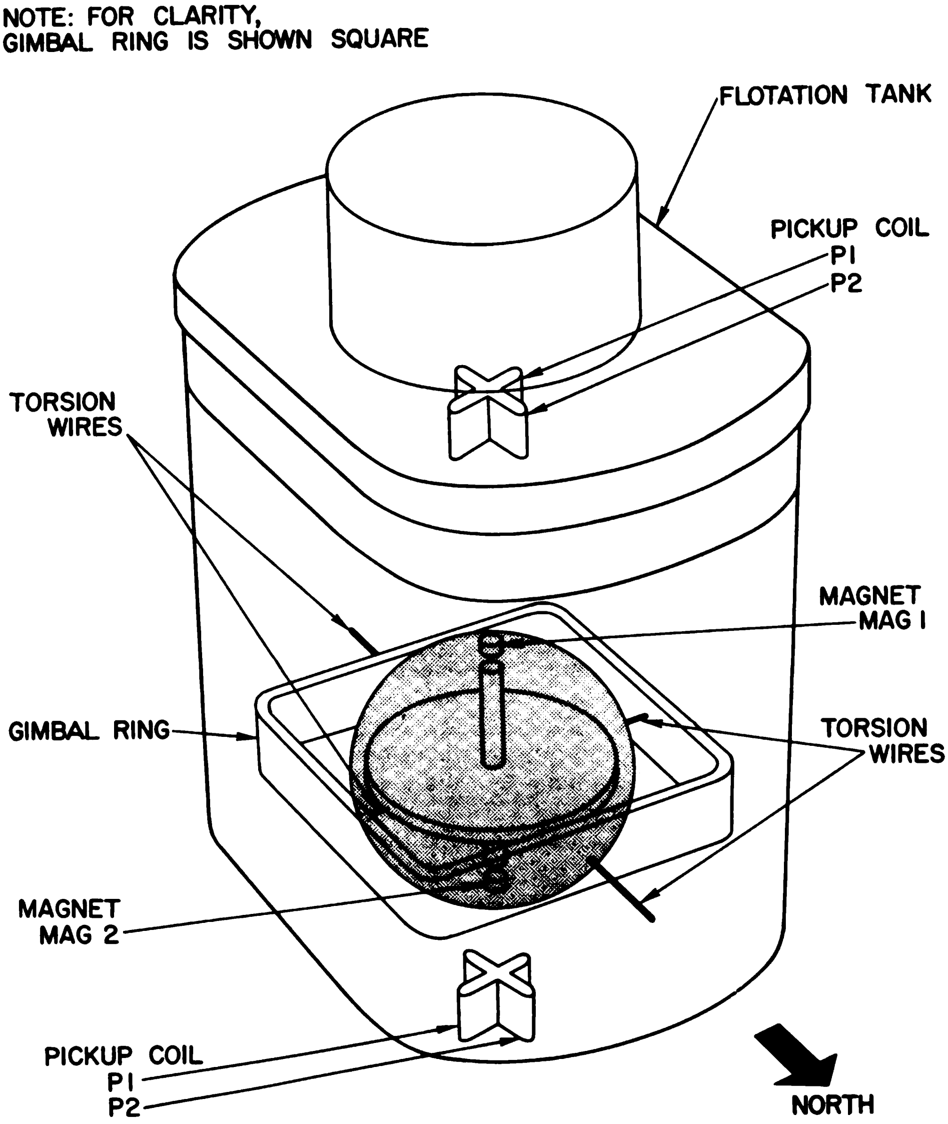
2. The azimuth gimbal is, in turn, supported by the level gimbal whose axis is in the horizontal while its reference is in the line-of-sight.

3. The level gimbal is, in turn, supported by the cross-level gimbal whose axis is in the horizontal while its reference is across the line-of-sight.

4. The cross-level gimbal is, in turn, supported by the director train gimbal whose axis is in the deck plane while its reference is the line-of-sight.

5. The roll gimbal is positioned by the azimuth gimbal but uses the fore and aft axis of the ship as a reference.

While this system of gimbals may seem complicated, it should be understood that each gimbal serves a very definite and necessary purpose. At this point you only need to know that they either introduce a new reference from which desired angular quantities are measured or to introduce torque corrections to the sensitive element to overcome unwanted drift or precession.



31. PHANTOM VIEW OF SENSITIVE ELEMENT

SPINNING THE GYRO WHEEL

As in the Stable Element Mk 6, the gyro wheel is the rotor of an electric motor. In the Mk 16 the motor operates on 3 phase 400 cycles.

POSITIONING THE GYRO AND MEASURING GYRO MOVEMENT

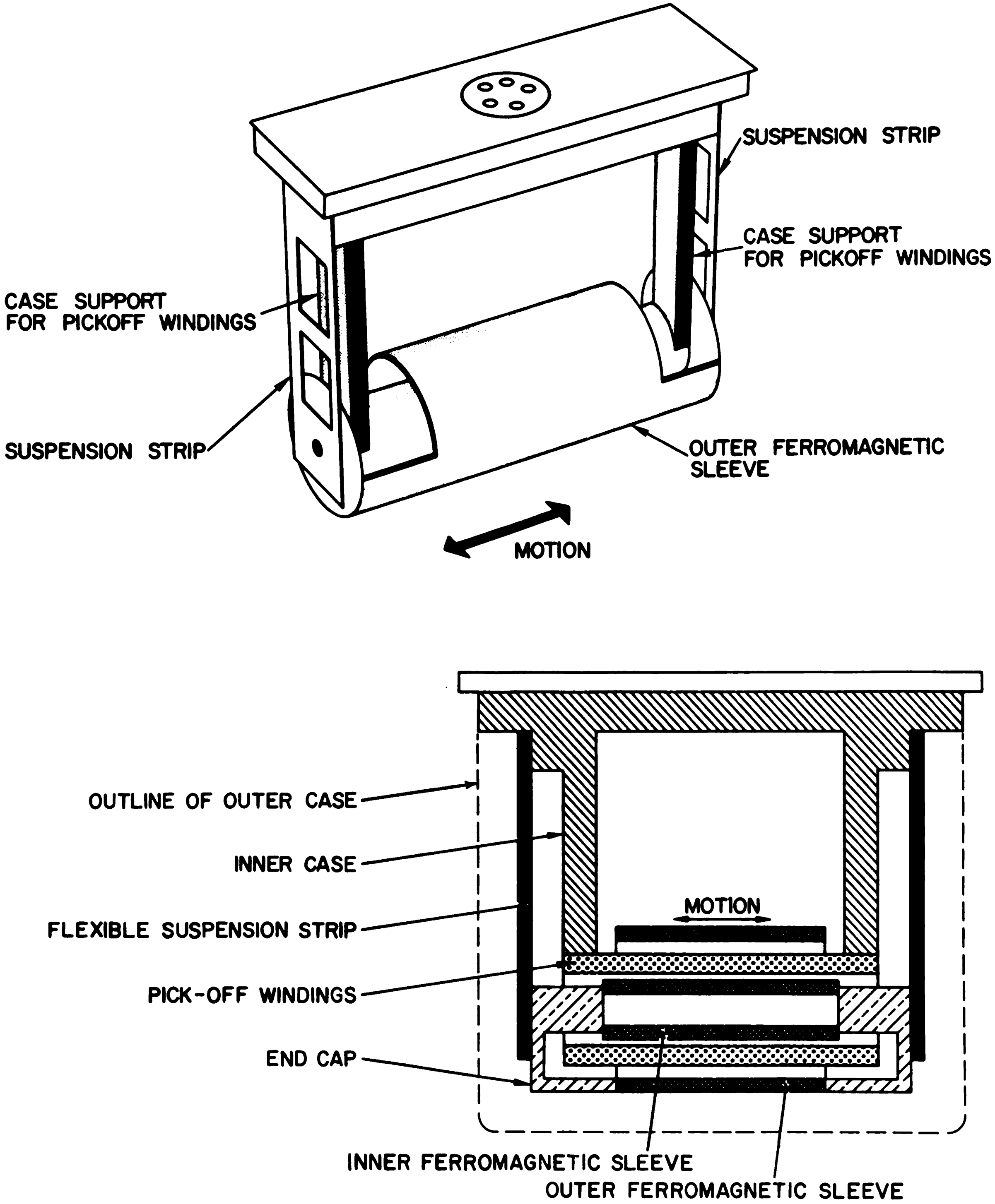
To bring the sensitive element to the vertical and continue to furnish it with a vertical reference, a system of pendulums is utilized. There are two sets of pendulums. The run pendulums, illustrated on the facing page, are heavily damped pendulums mounted on the azimuth gimbal so that one pendulum is oriented north-south and the other is oriented east-west. As you will remember, the sensitive element is oriented to a north-south reference. The run pendulums serve to give the sensitive element its vertical reference while running and aid in bringing it to the vertical when starting. The other set of pendulums, called the rapid settle pendulums, are referenced to the line-of-sight and are mounted on the level gimbal so that their rotation axes are at right angles. The rapid settle pendulums are only lightly damped and therefore have a fast response to tilts.

While the sensitive element is initially being brought to the vertical, the outputs of the rapid settle pendulums are added to the outputs of the gyro pickups and the main run pendulum pick-offs. The pick-off windings of the rapid settle pendulums are arranged the same as in the run pendulums. Since the rapid settle pendulums are mounted on the level gimbal which is referenced to the line-of-sight, it is not necessary to convert these voltages to the line-of-sight. When the stable element is up to speed and oriented to the vertical, the outputs of the rapid settle pendulums are disconnected from the servos because, due to the light damping, their high sensitivity to movements of the ship could introduce errors in level and cross-level.

After the sensitive element has been brought to the vertical, signals for stabilizing the cross-level and level gimbals originate in two electromagnets and two pickup coils in the sensitive element, and in pickup coils in the run, or main pendulum assemblies.

Let us first consider the electromagnets and the pickup coils in the sensitive element. The electromagnets are fixed to the inside of the gyro sphere and in line with the spin axis. The pickup coils are mounted inside the flotation tank close to and in line with the electromagnets so that the magnets can induce voltages in the coils. The coils are arranged so that when they are centered under the electromagnets, the voltages induced in them are equal and opposite and cancel each other. If, however, the gyro sphere is not lined up with the pickup coil centers, the induced voltages in the coils are not equal and there is a voltage output from them. The amplitude of this voltage is proportional to the amount of tilt or, more exactly, to the angle between the vertical spin axis and the top-to-bottom reference line of the flotation tank, which is vertical when there is no tilt. Whenever there is a difference between the gyro spin axis and the axis of the flotation tank there will be, as when the ship rolls, voltages induced in the pickup coils. These voltages will be combined with certain other voltages and become inputs to the level and cross-level servos. The servo outputs will drive the level and cross-level gimbals and these in turn will reposition the azimuth gimbal and the flotation tank and cause the tank to position itself so that the pickup coils are again directly in line with the electromagnets of the gyro sphere.

As you will remember, the proper reference for the gyro spin axis is the vertical. This reference while in normal operation is furnished by the run, or main pendulums. If the azimuth gimbal, upon which these pendulums are mounted, is not positioned to the vertical, there will be movement of the pendulums. When movement of the ferromagnetic sleeves of the pendulums occurs, pick-off voltages will appear that will be added to the voltages induced in the gyro pickup coils as the input to the level and cross-level servos. The inputs from the gyro pickup and run pendulum pick-off are referenced to the north-south axis since they originate in devices mounted in the sensitive element and on the azimuth gimbal. Since the angles of level and cross-level are referenced to the line-of-sight, it is necessary that these voltages be converted into their coordinates in the line-of-sight and across the line-of-sight. This is accomplished by the use of resolvers,


SUSPENSION STRIP
CASE SUPPORT FOR PICKOFF WINDINGS
CASE SUPPORT FOR PICKOFF WINDINGS
SUSPENSION STRIP
OUTER FERROMAGNETIC SLEEVE
MOTION
OUTLINE OF OUTER CASE
INNER CASE
FLEXIBLE SUSPENSION STRIP
PICK-OFF WINDINGS
END CAP
MOTION
INNER FERROMAGNETIC SLEEVE
OUTER FERROMAGNETIC SLEEVE

NOTE:
INNER AND OUTER FERROMAGNETIC SLEEVES AND PICK-OFF WINDINGS ARE CONCENTRIC. ONLY FERROMAGNETIC SLEEVES MOVE WITH SUSPENSION STRIPS.

32. RUN PENDULUM

whose stator inputs are the outputs of the gyro pickup and the run pendulum pick-off and whose mechanical rotor inputs are true target bearing. The outputs of the resolvers will then be corrected to the line-of-sight.

To compensate for apparent gyro rotation as the earth rotates from west to east, the latitude correction is used to cause an easterly precession. The precessional rate depends on the latitude and is maximum at the equator. The precession is caused by offsetting the pickup coils of the gyro with respect to the spin axis magnets in the north-south plane. This offset creates torsion wire twist on the east-west pair of torsion wires. This wire twist exerts a force on the gyro which causes the correct precession. A constant wire twist, for the particular latitude in which the equipment is operating, is kept on the gyro sphere to keep it precessing in an easterly direction. To maintain the proper twist, a voltage proportional to the cosine of the latitude of the ship is obtained from a latitude potentiometer. This voltage is sent through a resolver to convert it to line-of-sight coordinates and then applied to the level and cross-level servos. These servos will drive to move the tank spin axis in a north-south plane. Since the gyro spin axis will not move due to its rigidity in space, a signal will be induced in the north-south pickup coil and the east-west torsion wires. When the pickup coil voltage is of equal amplitude but of opposite phase to the latitude signal, the servos will stop and the required twist will be maintained.

In addition to apparent rotation, other inherent frictions and drags may cause unwanted precession of the gyro. These built-in errors cannot be completely compensated for in manufacture and installation. To overcome these errors, an east-west bias and a north-south bias potentiometer are adjusted, with the ship at rest, to bring a set of level bubbles mounted atop of the roll gimbal to the center of their glasses. This correction is checked about once a month but it is seldom necessary to change it.

Changes in ship speed affect the pendulums. Due to the heavy damping of the run pendulums, their movement from the vertical would be slow and would cause an exponential voltage change to appear on their pick-offs. To overcome this, a voltage proportional to the change of ship's speed is used to bring the pendulums back to the vertical reference. Since this ship's speed change will occur in the direction of the ship's head and since the run pendulums are mounted on the azimuth gimbal and are consequently referenced to north-south, it is necessary that the correctional voltage be converted by use of another resolver from ship's course reference to north-south reference. The correctional voltage will be applied to portions of the pendulum pick-off coils which will act as force motors to bring the pendulums back to the vertical.

The measured angular quantities of level and cross-level are transmitted to the director and the computer by means of synchros.

RADAR SET

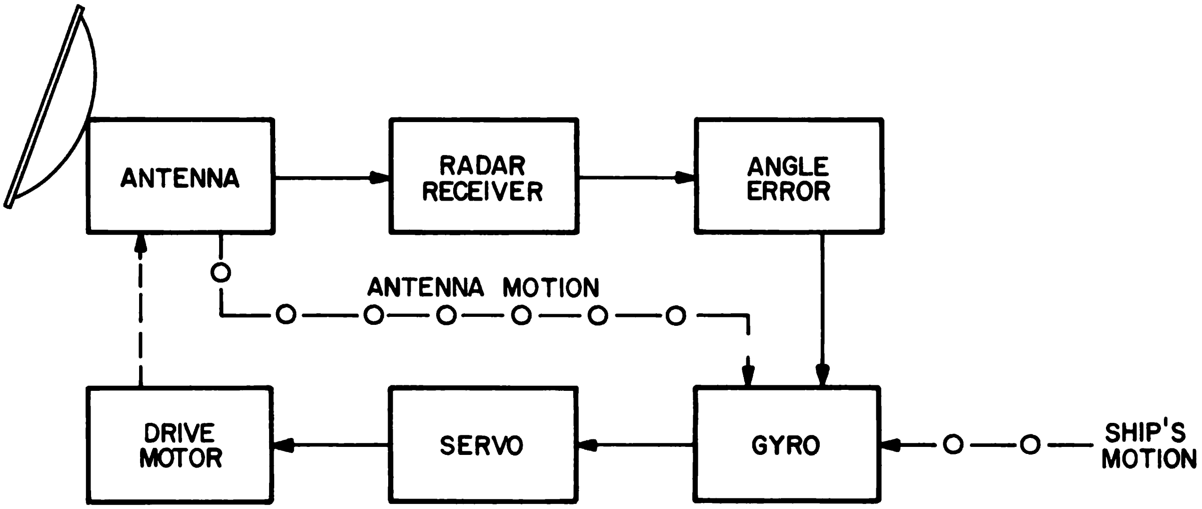
Radar Set AN/SPG 55-B is the track and guidance radar used with MFCS Mk 76 Mod 2. This fire control system is used with the Terrier missile. The radar must be capable of rapidly and accurately acquiring and tracking designated targets and providing missile guidance information.

In the Mk 6 and Mk 16 Stable Elements you were shown how a free gyro was used to establish a vertical reference. Ship's motion was measured about this reference and corrections generated for use in solution of the fire control problem by the computer. Missile fire control systems must also be stabilized and effects of ship's motion eliminated. The stable element is not adequate for the degree of sensitivity and response required in missile systems. In missile systems, the stabilization of the line-of-sight is accomplished much more rapidly by using the line-of-sight as the reference for the gyro system.

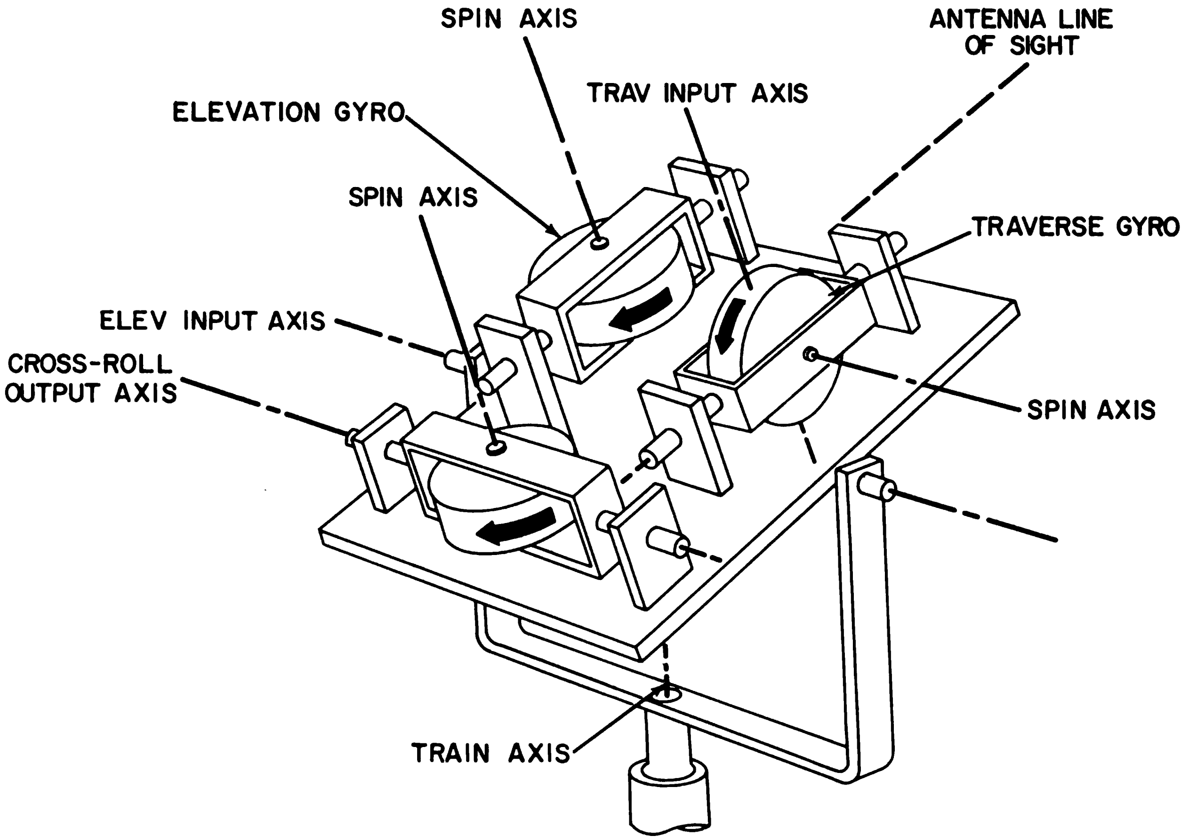
PURPOSE OF AN/SPG 55-B AUTOMATIC TRACKING CIRCUIT

HIG units are used in the automatic radar tracking (angle servo) circuits of the AN/SPG 55-B to stabilize the line-of-sight in the presence of ship's motion. That is to say, the radar beam is stabilized in space regardless of ship's motion. The tracking system may be considered as six major units: the radar receiver, the angle error circuits, the gyro unit, the power drive servo circuits, the power motor, and the radar antenna. Operating together, these groups of equipments function as a large servo mechanism to position the radar antenna.

Below is a block diagram which illustrates the tracking system. The target echos received by the receiver from the antenna are converted to tracking errors in the angle error circuits. These tracking errors are applied to the gyro torque generator which applies a torque to turn the gyro output shaft. The signal generator connected to the same shaft now has an output which controls the servo circuits which provide drive signals to the antenna drive motors. The antenna now positions itself so the radar beam tracks the target. Movement of the antenna causes a torque about the gyro input axis which causes the gyro to precess back toward its original position, thus nulling the signal generator output. Any ship's motion (pitch and roll) also causes a torque about the input axis of the gyro so that at all times the signal generator output is a function of antenna motion and ship's motion.



33. BLOCK DIAGRAM OF AUTOMATIC TRACKING CIRCUIT



34. GYRO ORIENTATION

GYRO ORIENTATION

The radar set AN/SPG 55-B utilizes three HIG units. The orientation of the gyro axes is illustrated above. For simplicity, only a pictorial representation of the gyroscopes is shown. In reality the platform on which the gyros are mounted would be the inner walls of the gyro stabilization unit mounted on the main antenna. The fork-like support on which the platform is mounted is representative of the function served by the left and right elevation shaft housing assemblies.

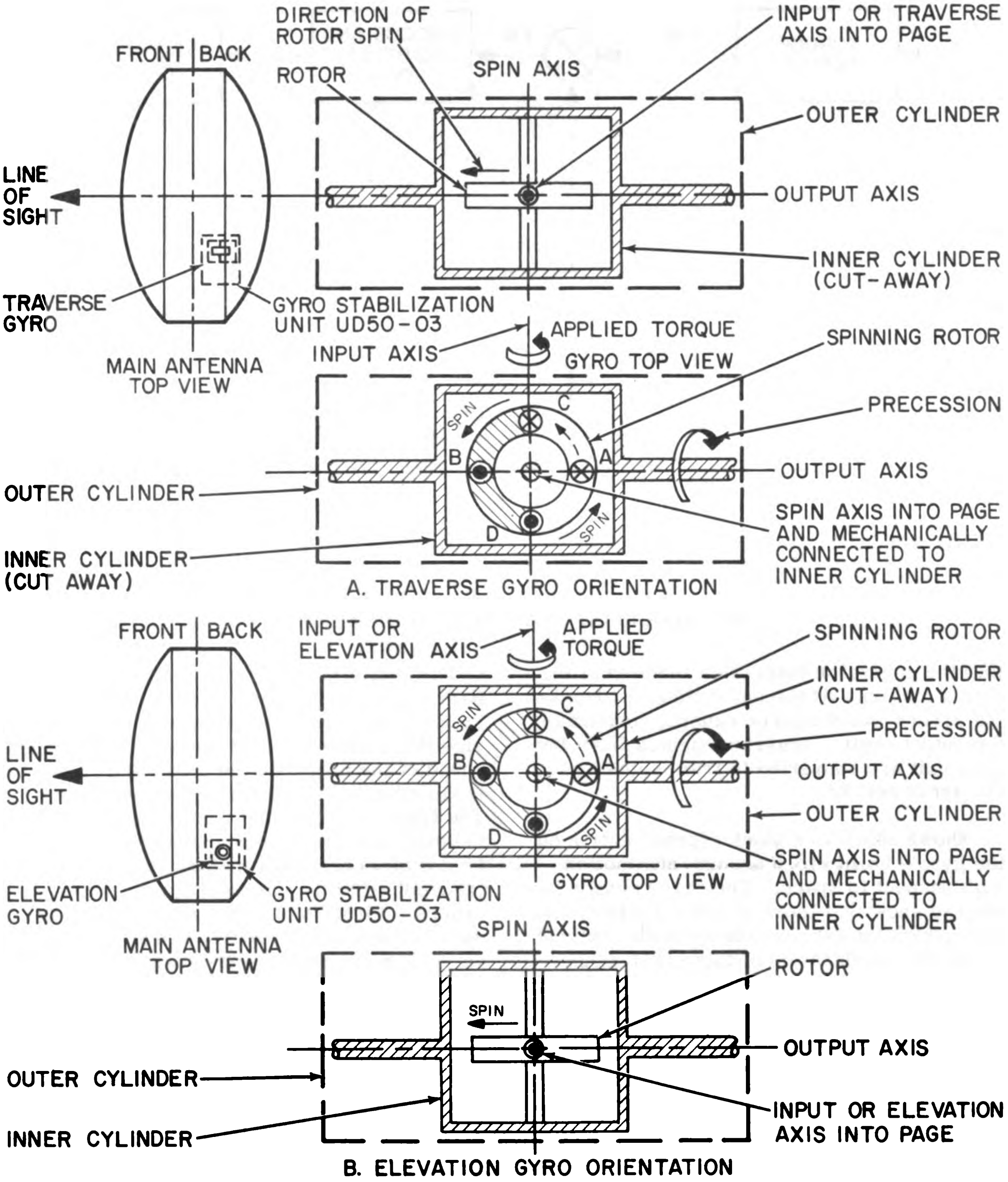
FUNCTION OF THE GYROS

The function of either the elevation or the traverse gyro is to provide an output signal whenever there is a motion of the main antenna around its respective axis. The motion may be either a function of ship's motion (roll and pitch), antenna drive motor action, or a combination of both motions. The outputs of the elevation and traverse gyro signal generators are used for stabilization. The output of the cross-roll signal generator is not used directly for antenna stabilization: however, the output signal is used in the Mk 119 Computer to determine the angular rate of the target.

MOTION ERROR SENSING

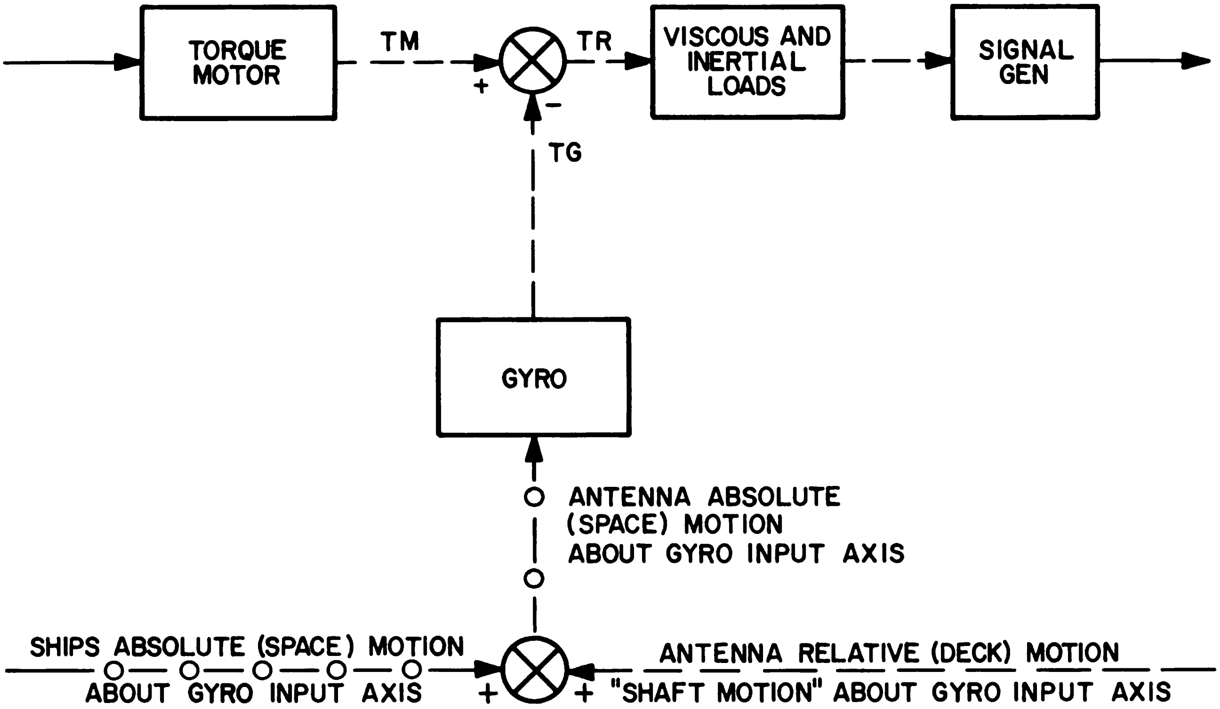
The illustration on the facing page shows the orientation of the gyro rotor within the HIG unit for both traverse and elevation. With the exception of the axis orientation, the discussion of the traverse gyro will apply to the elevation gyro.

For the traverse gyro, you will note that the spin axis is in the horizontal plane and perpendicular to the antenna line-of-sight. The output axis is along the line-of-sight and the input axis is in the vertical plane



35. GYRO ROTOR ORIENTATION

perpendicular to the line-of-sight. The input axis is the traverse axis about which the antenna rotates in the traverse plane. Assume a torque is applied to the input axis due to ship's motion. This torque will cause the gyro to precess about the output axis. The signal generator rotor, mechanically fastened to the output axis, will now be positioned such


TORQUE MOTOR
TM
TR
+
−
VISCOUS AND INERTIAL LOADS
SIGNAL GEN
TG
GYRO
ANTENNA ABSOLUTE (SPACE) MOTION ABOUT GYRO INPUT AXIS
SHIPS ABSOLUTE (SPACE) MOTION ABOUT GYRO INPUT AXIS
+
+
ANTENNA RELATIVE (DECK) MOTION "SHAFT MOTION" ABOUT GYRO INPUT AXIS

36. BLOCK DIAGRAM OF ERROR SENSOR

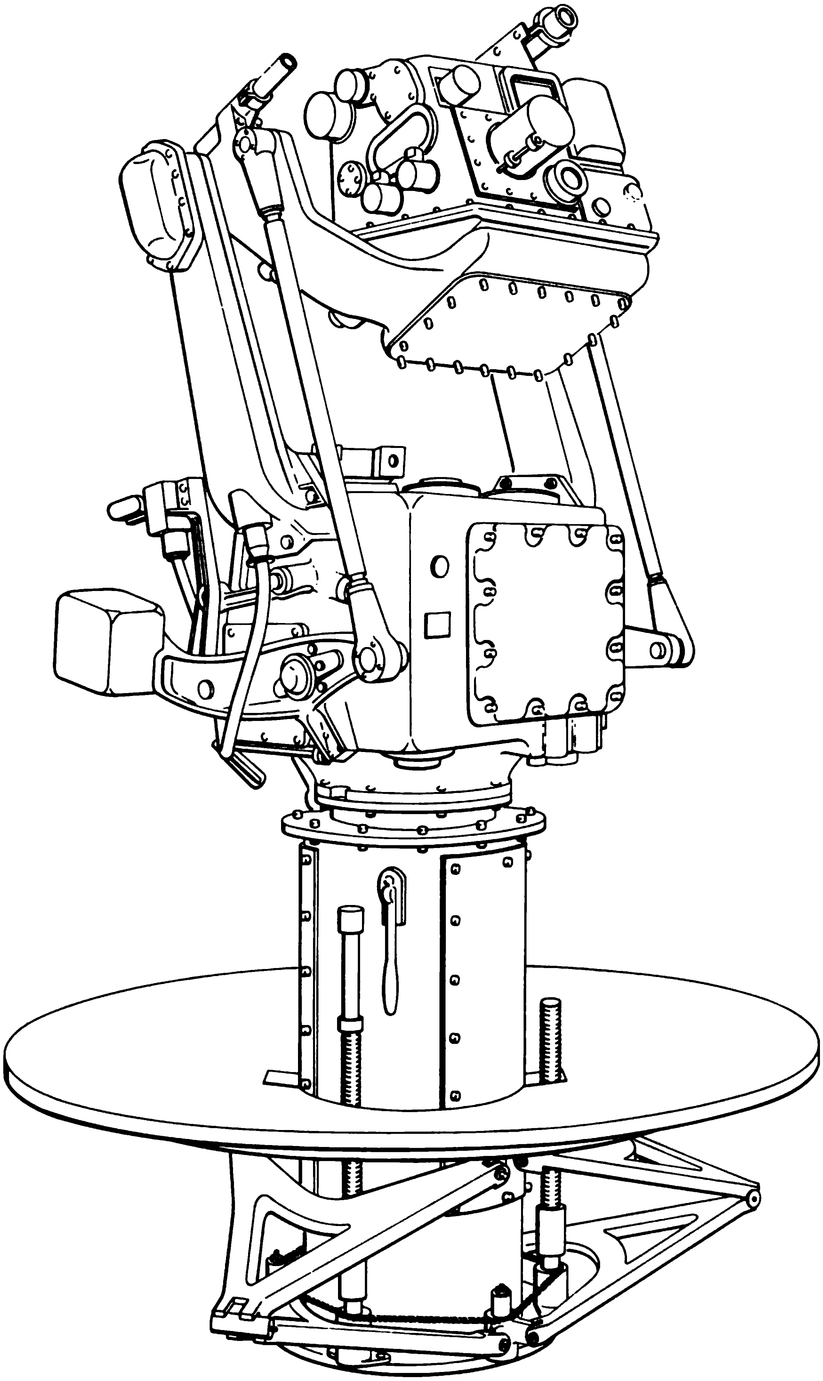
that the generator output is a function of the ship's motion. At the same time any tracking errors would also be causing rotation of the output shaft. Traverse signals from the gyro unit are converted to train signals in the servo section.

Shown above is a block representation of the gyro's ability to sense antenna motion with respect to space. The error sensor is used to show that there are two distinct motions which the gyro senses and adds together. A physical explanation of this error sensor is given in the following statement. If the ship were to pitch or roll such that the ship's motion about the gyro's input axis were equal and opposite to the rate at which the antenna motors were moving the director with respect to the deck, the gyro torque Tg would be zero.

FUNCTION OF MK 29 GUNSIGHT

The Mk 29 Gunsight is a component of GFCS Mk 63. GFCS Mk 63 is a shipboard mounted antiaircraft fire control system which directs the fire of 3"/50, 40-mm, or 4" British guns. The primary purpose of GFCS Mk 63 is to provide train and elevation orders which point the gun along the line-of-fire. The Mk 29 Gunsight contains two gyros to position mirrors which cause the line-of-sight to be offset so that the sight case points ahead of the target by the lead angle. This is called a disturbed-line-of-sight system. The train and elevation components of the the sight and director positions (includes lead angles) are measured by synchros and transmitted to the gun as train and elevation orders. Pickoffs on the gyros provide signals to position the radar antenna, mounted on the gun, along the line-of-sight. The director pointer positions the gunsight in both train and elevation to keep the reticle of the gunsight centered on the target image. The image may be made up from radar information fed into the optical system for blind tracking, or an optical image of the target. The gunsight is shown on the facing page.

In order to develop the correct lead angle, various factors must be considered. Lead angles are composed of individual components which compensate for target angular motion, super-elevation, range rate, drift, wind, cross-roll, and initial velocity of the projectile. The Mk 29 Gunsight uses gyros to solve for the correct lead angle.

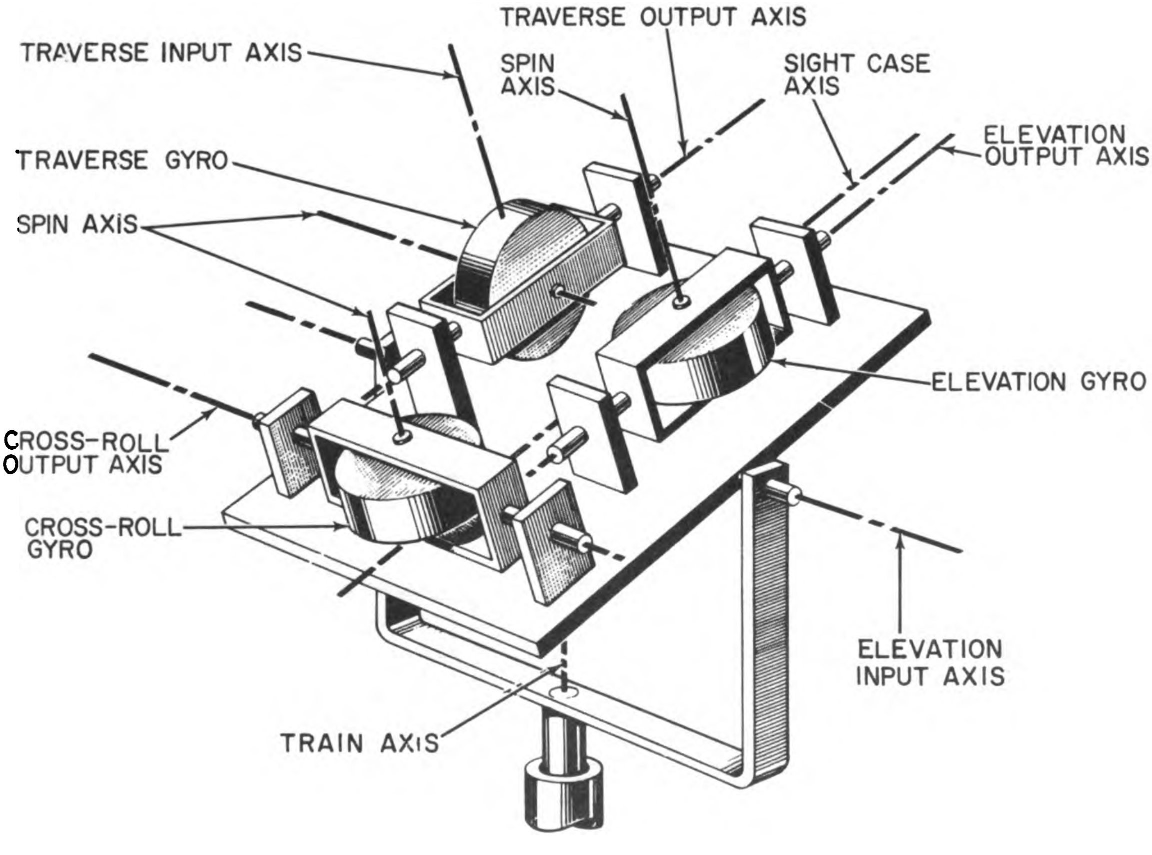


37. DIRECTOR PEDESTAL WITH GUNSIGHT IN PLACE

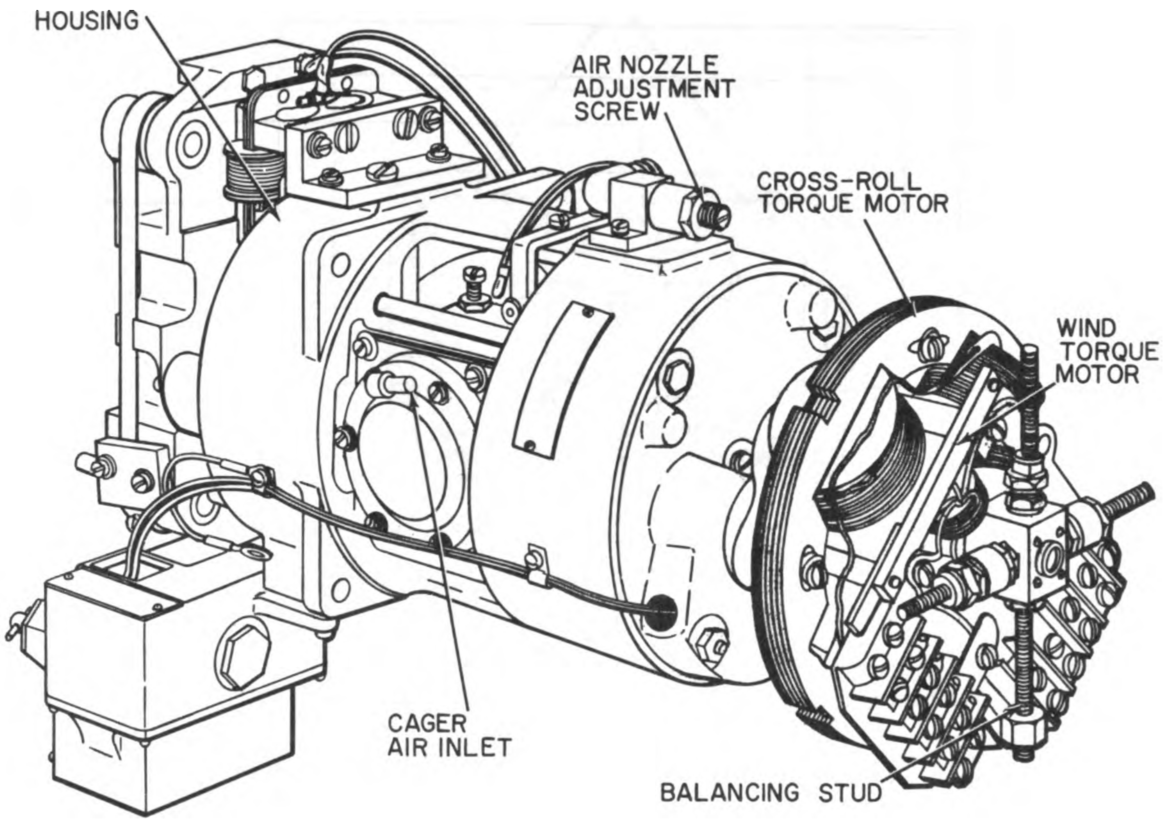
THE GYROS

As stated earlier, the gunsight contains two gyros. These are the traverse gyro and the elevation gyro. An additional gyro is required for cross-roll correction. This third gyro is mounted in the cross-roll cradle of the director head. However, the action of the three gyros is as if they were mounted as shown below. By applying the rules for precession you can see that the elevation gyro will precess only when moved in elevation, the traverse gyro will precess only when moved in train, and the cross-roll gyro will precess only when the director is rotated around the sight case axis (line-of-fire).

The gyros used are air driven, restrained, rate-of-turn gyros. The traverse and elevation gyros are mechanically coupled to the traverse and elevation mirrors which deflect the line-of-sight as the gyros precess due to the angular velocity. The remaining lead angle components are developed by weights and torque motors which increase or decrease the tilt of the gyro. Damping is used to provide smooth tracking by preventing instantaneous response to tracking errors. The gyros may be caged to eliminate the effects of angular velocity during acquisition. Pickoffs are used to provide information used in cross-roll correction and to position the radar antenna. The traverse gyro is shown on the facing page.



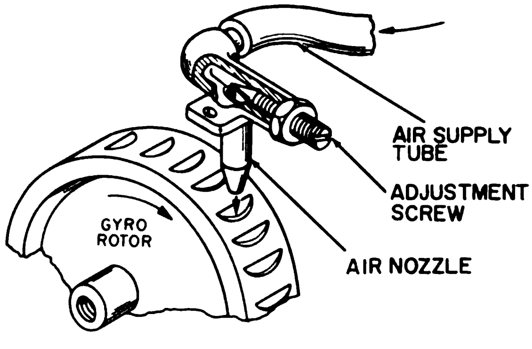
38. ORIENTATION OF GYRO AXES



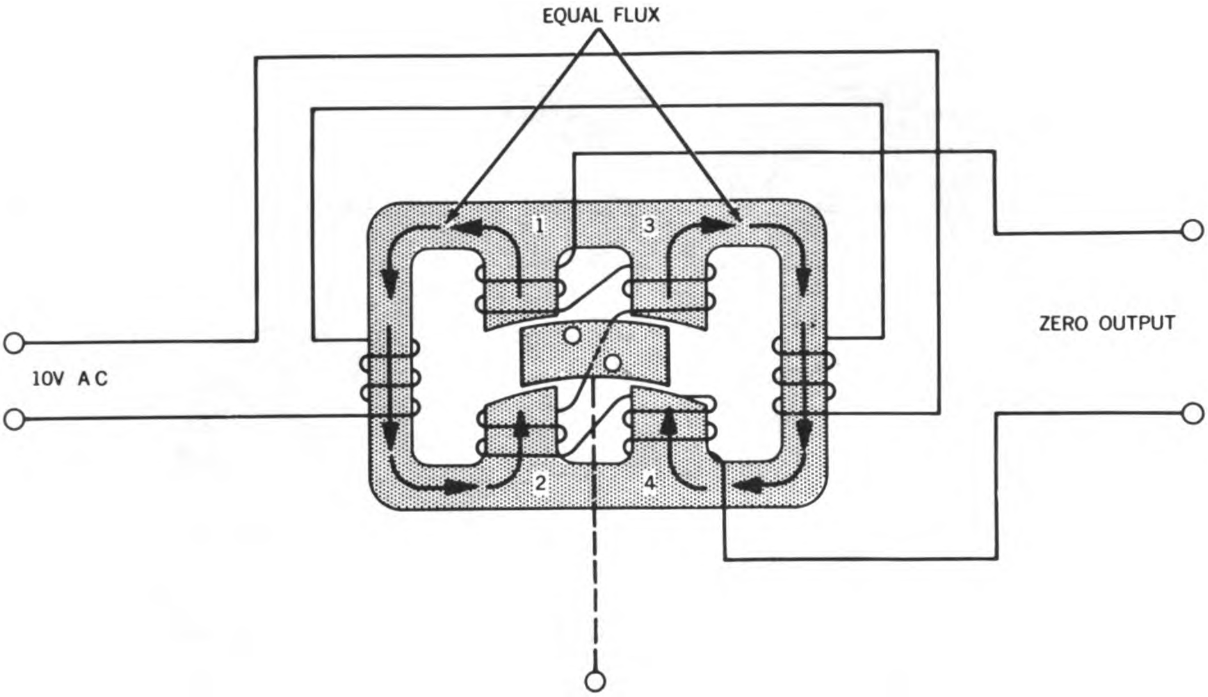
39. TRAVERSE GYRO

SPINNING THE GYRO WHEEL

Compressed air from a nozzle, directed against buckets in the rim of the rotor, rotates the rotor at a nominal 8,300 rpm. The air is circulated in a closed system where it is filtered and dried to prevent corrosion and regulated to keep the rotor speed constant. The precessional torque of the gyro is dependent upon rotor speed and the gunsight is calibrated on the basis of a relationship between torque and tracking rate. The rotor construction is shown in the adjacent column.



40. GYRO ROTOR



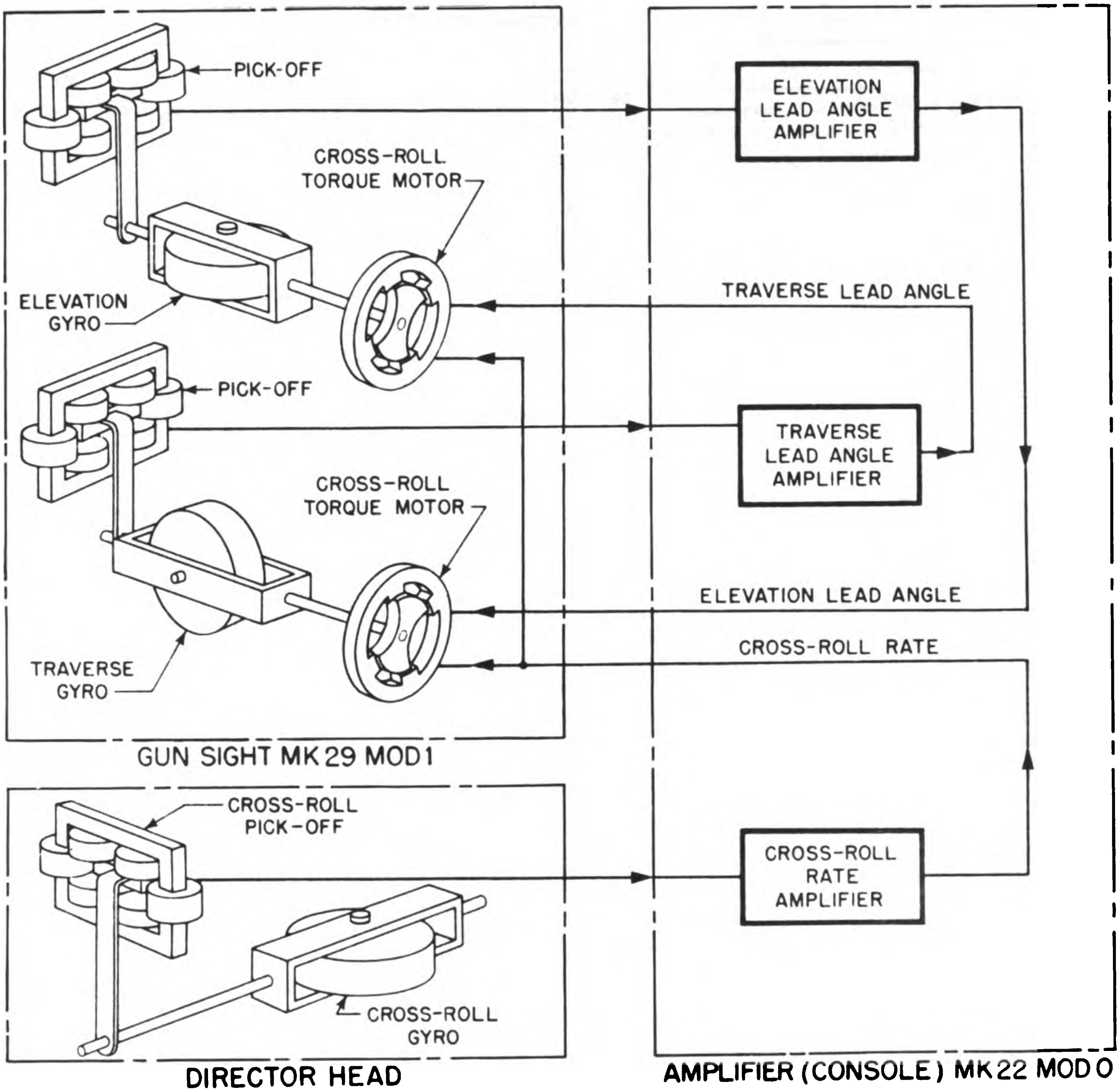
41. PICKOFF TRANSFORMER - MOVING ELEMENT IN CENTER

MEASURING GYRO MOVEMENT

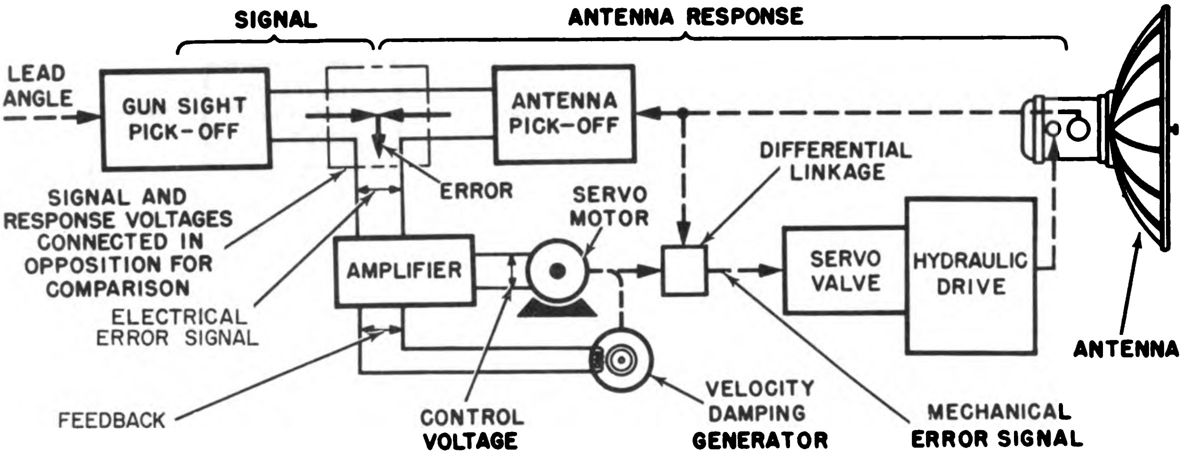
As stated earlier, information concerning gyro position is used to position the radar antenna along the line-of-sight. The position information is also used in the cross-roll correction system. The position information is obtained by use of a moving core transformer pickoff as shown above.

The laminated, high permeability - steel stator of the transformer has four internal pole faces. Two primary coils are wound in series on the ends of the stator. The secondary coils are wound on the poles such that the voltage induced in 1 and 2 opposes the voltage induced in 3 and 4. A laminated, high permeability element is attached to the gyro output shaft and is displaced whenever the gyro precesses. As explained earlier, the displacement of the moving element causes an output voltage. The phase in relation to the primary voltage indicates the direction and the amplitude indicates the amount of movement.

The illustration on facing page shows the application of pickoffs in the cross-roll correction system. In order to develop correct lead angles, it is necessary for the traverse and elevation gyros to have their positions modified to compensate for cross-roll.



42. CROSS-ROLL SYSTEM

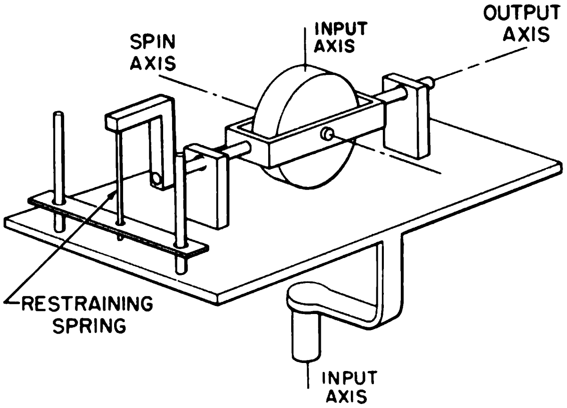


43. ANTENNA POSITIONING SYSTEM

Above is shown how a pickoff follow-up system is used to position the radar antenna.

POSITIONING THE GYROS

As the gunsight is moved in traverse and elevation to track the target, the gyros are measuring the lead angles. The lead angles are a function of target angular rate and prediction time. Prediction time is a function of range. At long ranges the lead angles must be large to allow time for the projectile to intercept the target. The drawing below represents the rate-of-turn gyro used in the gunsight.

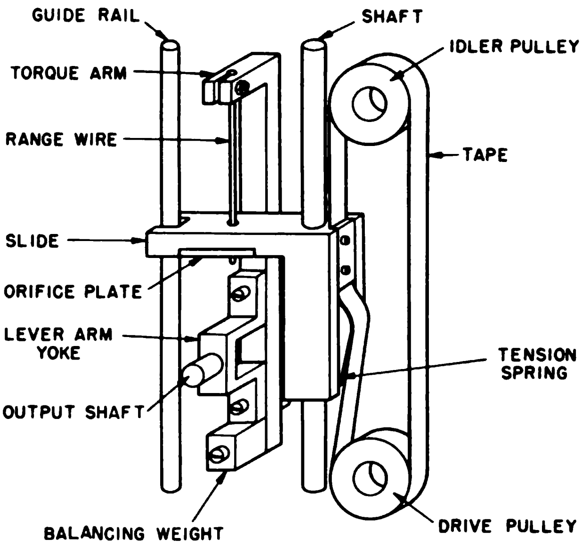


44. RATE-OF-TURN GYRO

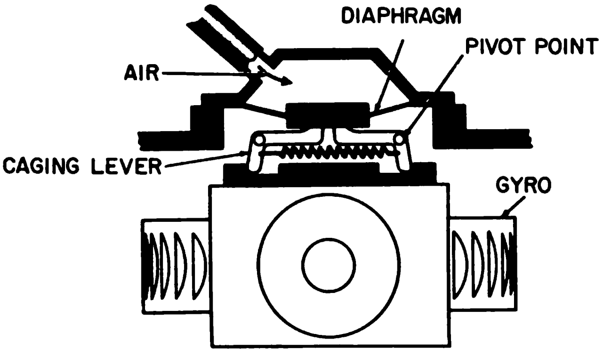
The rate of gyro precession is determined by the target's angular rate and the amount of movement is controlled by the restraining spring. The amount of restraint is a function of the spring's length. A short spring will offer more restraint than a long spring. Varying the length of the spring as a function of range will provide for the proper prediction time.

On the facing page is shown the arrangement used in the Mk 29 Gunsight to vary the length of the restraining spring. Radar range information or manual insertion of range causes the system to drive to a position which represents range. The effective length of the restraining spring (range wire) is continuously varied as the range changes. For long ranges the wire will be longer and hence offer less restraint. As a result, larger lead angles will be developed.

During acquisition of a target, the tracking rates generated are usually much greater than the correct rates. If allowed to precess during acquisition, the gyro will be slow to recover and reach the correct lead angle. To prevent excessive tilt, the traverse and elevation gyros are caged at the zero position during acquisition. The illustration on facing page shows the caging device. The gyro caging devices are operated manually by the

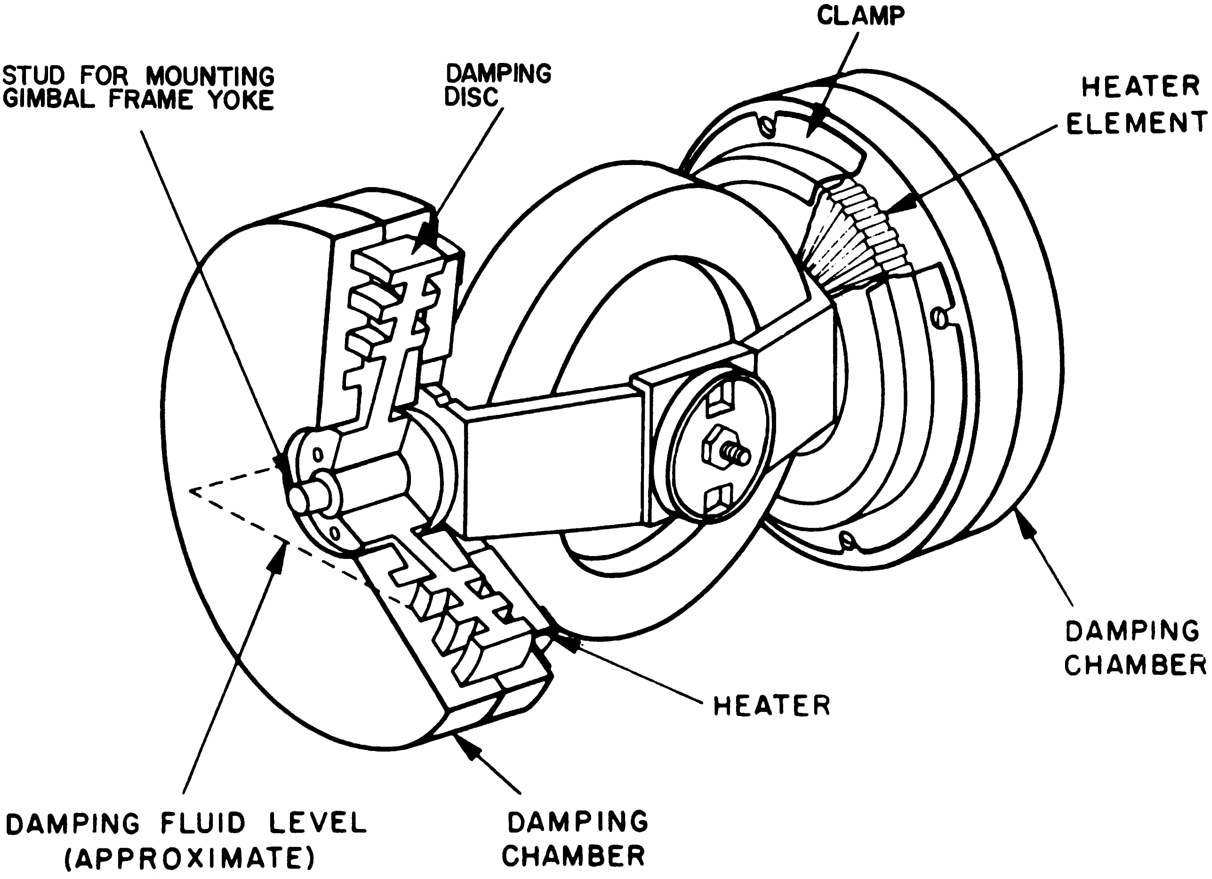


45. RANGE WIRE AND SLIDE ASSEMBLY



46. CAGING DEVICE

director operator or automatically if a target acquisition unit is used. When the caging device is operated, compressed air enters the device and forces a diaphragm against two levers which spread apart and engage slots on the gyro gimbal to prevent tilting of the gyro.


CLAMP
STUD FOR MOUNTING GIMBAL FRAME YOKE
DAMPING DISC
HEATER ELEMENT
DAMPING CHAMBER
HEATER
DAMPING FLUID LEVEL (APPROXIMATE)
DAMPING CHAMBER

47. DAMPERS AND HEATERS

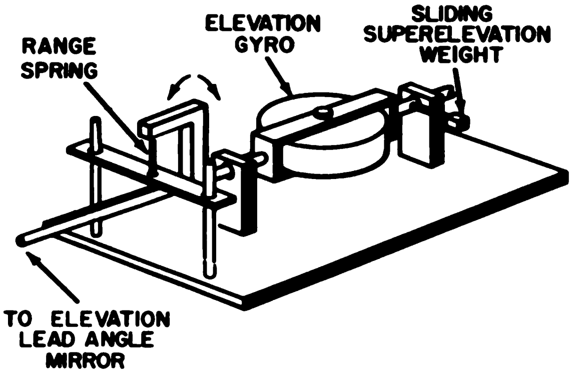
The damping system used to smooth the action of the traverse and elevation gyros is shown above. The damping device consists of discs attached to the gyro output shaft and a housing filled with a viscous fluid. The restraining force of the fluid on the gyro is directly proportional to the rate of change of the lead angle. Heaters are used to compensate for temperature changes which would change the viscosity.

You have seen how the gyros were restrained to measure the angular velocity component of the required lead angles. To complete their function, the gyros must modify the amount of tilt for the additional factors of drift, wind, superelevation, and cross-roll. As previosuly stated, torques will be applied to the gyros to compensate for these factors. Weights suspended from lever arms will supply the necessary torque for drift and superelevation corrections. Torque motors provide the torque for wind and cross-roll corrections.

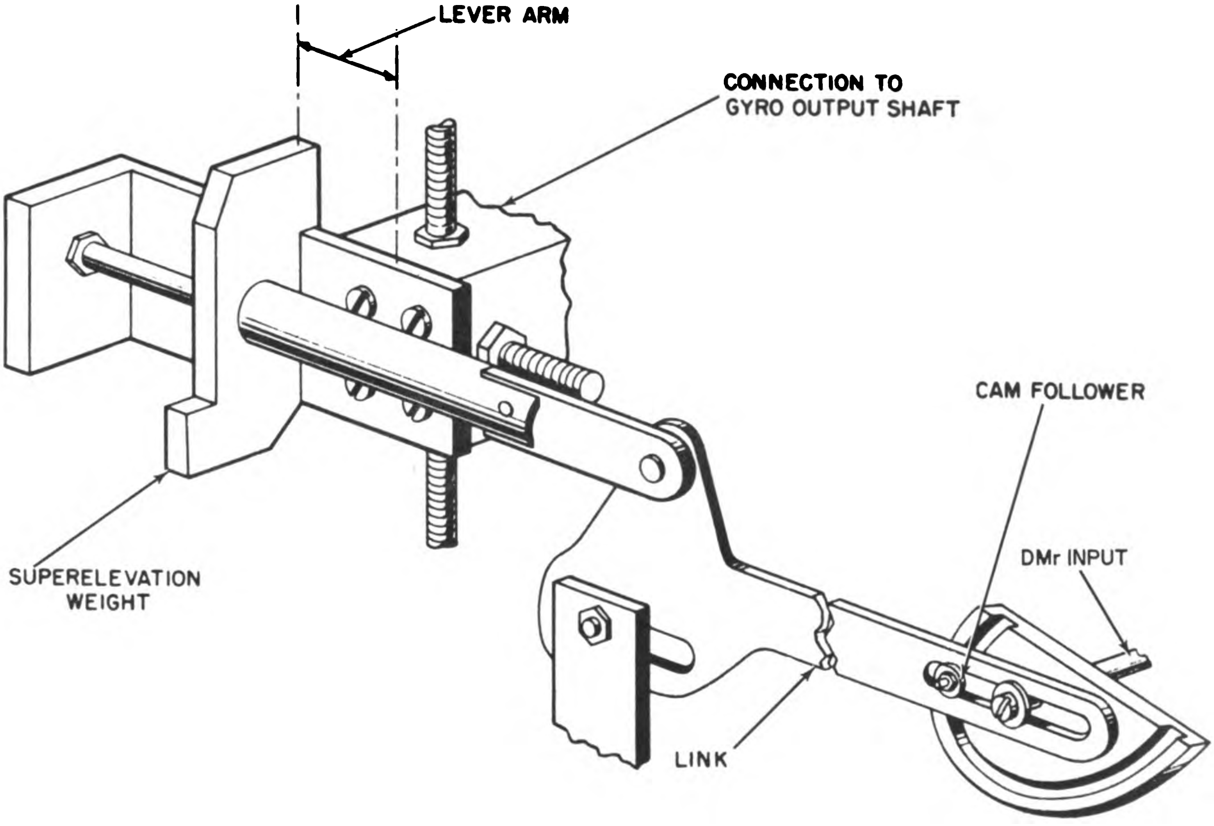
Superelevation is a correction made to compensate for the affect of gravity on the projectile. The correction is a function of range and elevation angle. Because the amount of torque must change, the superelevation weight on the elevation gyro shown at right must be adjustable.

Below is shown the arrangement to change the position of the superelevation weight as a function of range. The weight is positioned by a cam follower driven by range rate.

Cross-roll will also affect the torque applied by the superelevation weight on the elevation gyro. To offset this, the traverse gyro has a fixed superelevation weight.

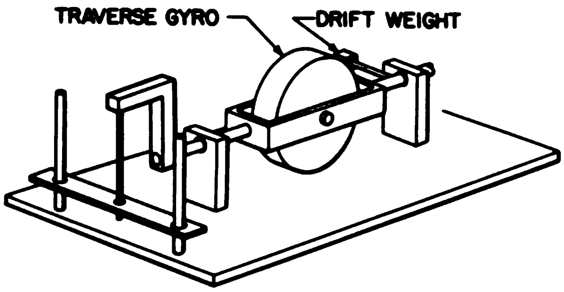


48. SUPERELEVATION WEIGHT



49. SLIDING SUPERELEVATION WEIGHT SYSTEM

Drift is an effect caused by various forces acting on the spinning projectile. A drift weight is attached to a lever arm on the traverse gyro as shown below. Variations in the correction due to range rate and cross-roll are not sufficient to require an adjustable weight.



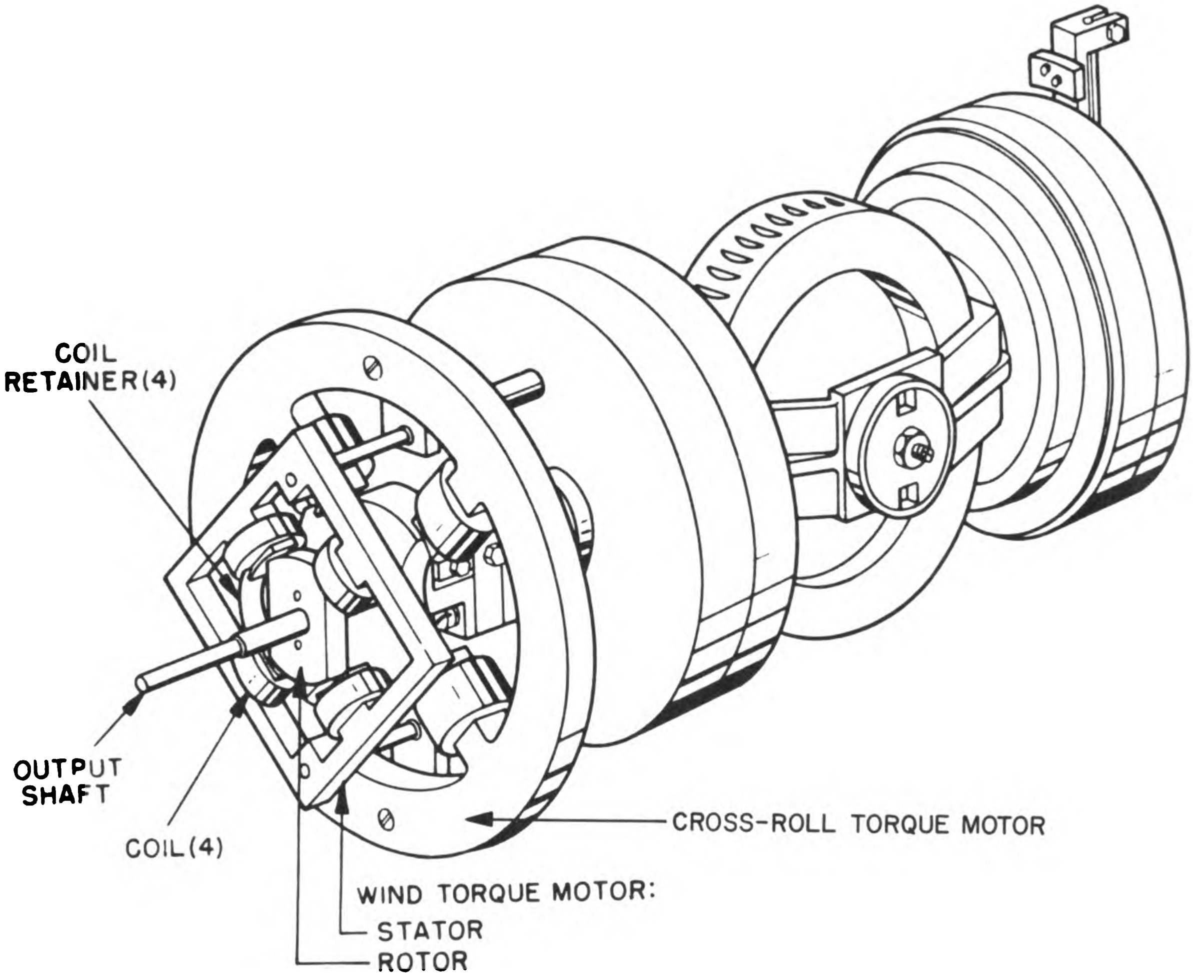
50. DRIFT WEIGHT

The effects of wind on the projectile during flight vary as a function of range, elevation, wind direction, and wind velocity. A wind system computes the required corrections and applies the correction to the elevation and traverse gyros through torque motors.

Torque motors are also used to correct for effects of cross-roll. The inputs to the motors are from the cross-roll correction system. Both of the torque motors are shown on facing page. The motors are similar except that the wind motor has one coil instead of two on each stator pole and is smaller in size because less torque is required.

REVIEW AND SUMMARY

In this topic you were shown how gyroscope principles were used in four pieces of fire control equipment. Stable Elements Mk 6 and Mk 16, Radar Set AN/SPG 55-B, and the Mk 29 Gunsight were selected because they are all presently used in the fleet and they utilize gyro mechanics in various ways. It is not the purpose of this topic to teach you any of these equipments; but rather to illustrate the application of the gyroscope.



51. GYRO UNIT - WIND AND CROSS-ROLL TORQUE MOTORS

QUIZ:

1. Define gyroscope.

2. What are the two properties of a gyroscope?

3. List three sources of mechanical drift.

4. The rotation of the earth causes an apparent gyro precession in which direction?

5. How is compensation for the apparent precession due to earth's rotation accomplished?

6. List the three gyro axes.

7. How can we compensate for mechanical drift in a gyro?

8. What is meant by the term "degree-of-freedom" as applied to gyros?

9. A "free gyro" is classified as a ______ degree-of-freedom gyro.

10. Define a rate gyro.

11. Define an integrating gyro.

12. Name several devices used in measuring gyro movement.

13. Which type of pickoff would be used where extreme accuracy is required?

14. List two basic types of erection systems.

15. Define the term "caging".

16. How is the gyro wheel spun in the Mk 6 Stable Element?

17. The Mk 16 Stable Element measures what quantities and what is their reference?

18. What type of erection system is used in the Mk 6 Stable Element?

19. What type of gyros are used in the AN/SPG 55-B radar?

20. What is the purpose of the adjustable range wire assembly in the Mk 29 Gunsight?

21. What is the purpose of the run pendulums in the Mk 16 Stable Element?

22. What motions or movements are sensed by the gyro unit in the AN/SPG 55-B Radar?

23. What type of pickoff device is used in the HIG units of the AN/SPG 55-B?

24. How are the rotors of the gyros spun in the Mk 29 Gunsight?

25. In the Mk 29 Gunsight gyros, what is the purpose of the damping fluid?

Section 2

NAVY MAINTENANCE MANAGEMENT SYSTEM (NMMS)

Topic No.	Topic Title	Page
1.	Introduction to NMMS	54

TOPIC 1: INTRODUCTION TO NMMS

YOU ARE NOW GOING TO LEARN:

1. The purpose of Navy Maintenance Management System (NMMS).
2. The divisions of NMMS.
3. The tools of Planned Maintenance System (PMS).
4. The tools of Maintenance Data Collection (MDC).

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Preventive and corrective maintenance.
2. Purpose of NMMS.
3. Divisions of NMMS.
4. The tools of PMS.
   a. The maintenance manual.
   b. The cycle schedule.
   c. The quarterly schedule.
   d. The weekly schedule.
   e. The maintenance requirement card.
5. The tools of MDC.
6. Review and summary.

INFORMATION AND DISCUSSION:

PREVENTIVE AND CORRECTIVE MAINTENANCE

Preventive maintenance is the sum of those actions that can be accomplished on a repetitive basis that contributes to uninterrupted operation of an equipment within design characteristics. It is maintenance to equipment which is done to prevent failures to the equipment; it is accomplished on a systematic, scheduled basis.

Corrective maintenance is the sum of those actions that are required to restore equipment to operation within a predetermined tolerance/limitation. It is maintenance to equipment which is done to correct a failure that has already occurred to the equipment; it is accomplished when it is necessary to restore equipment to proper operating condition.

PURPOSE OF NMMS

By OPNAV INST 4700.16A, the Chief of Naval Operations promulgated a Standard Navy Maintenance Management System for all PREVENTIVE maintenance in the United States Navy. It is a system designed to standardize preventive maintenance and to provide for the uniform accomplishment of all preventive maintenance. Such a system must also have a method of collecting, processing, analyzing, and distributing feedback information to enable commanders and bureaus to carry out their management functions in support of the fleet.

Previous maintenance programs and efforts usually fell short of desired goals because:

1. Nonuniform maintenance resulted in overmaintenance, undermaintenance, or improper maintenance and often contributed to, rather than prevented casualties.
2. Myriad reports were so unrealistic and unmanageable that they were falsified by many reporting stations. Even where ships or commands managed to comply with all the required reports, they became too great a task for BUSHIPS to handle. Accordingly, recipients were often forced to take action without studying the reports or to take no action at all.
3. Lack of real maintenance management at the command level resulted in varied individual ship departmental or sectional approaches influenced by personal preferences, idiosyncrasies, and guesswork.
4. Inexperienced maintenance officers were often called upon to carry out poorly or partially planned programs. With only a year or two of experience behind them, these officers were not

capable of implementing a program of such magnitude and depth. In addition, they often lacked the management tools and material support necessary.

5. Varying and conflicting maintenance documentation resulted in confusion. Which document took precedence: Bureau of Ships Technical Manual, manufacturers' instruction books, Type Commanders' Instructions and Notices, or drawings?

6. Poor material support is recognized as an age-old problem by everyone who has been involved in maintaining equipment. Lack of proper tools, materials, and parts has often made it impossible to accomplish a maintenance action.

The Planned Maintenance System was developed aboard ships in both the Atlantic and Pacific fleets. The drafters of the system took stock of the deficiencies of other systems and took special care to prevent their recurrence. Accordingly, the preventive maintenance required for all shipboard equipment has been defined and scheduled, down to the methods and tools to be used and the time and ratings required for accomplishment.

Once NMMS has been installed, it will supersede all existing maintenance programs. Where there is a difference between stated requirements of the planned maintenance system and other technical publications (i.e., BSTM, OP's, POMSEE, etc.), PMS will apply. In the event there is a difference of such significance that the reliability of the machinery is considered to be involved, the Type Commander should be informed accordingly.

DIVISIONS OF NMMS

The Navy Maintenance Management System will be considered in two parts: Planned Maintenance System (PMS) and Maintenance Data Collection (MDC).

PMS is designed to:

1. Reduce the complex maintenance of equipment to simple procedures which are easily identified and managed.

2. Define the preventive maintenance required, schedule and control its performance, describe the methods and tools to be used, and provide the prevention of or detection of impending casualties.

As an effective management system it will permit a ship to:

1. Forecast and plan manpower and material needs.

2. Plan and schedule maintenance.

3. Estimate and evaluate material readiness.

4. Detect areas for improving training and maintenance techniques.

MDC is designed to provide a uniform system for information collection, a central point for processing the collected data, and a distribution procedure to satisfy the needs of the technical bureaus and the operating forces. It will provide a means for repair activity workload planning and control and will ultimately be the vehicle whereby accomplishment of alterations, field changes, modifications, etc., is reported.

MDC provides a document for recording, at the source and by maintenance personnel, information concerning planned and corrective maintenance. This information is recorded by means of codes to permit machine processing. Each maintenance action is reported.

In addition to recording maintenance actions performed, the system further provides data concerning when the need for maintenance was discovered, how equipment malfunctioned, how many manhours were expended, which equipment was involved, what delays were incurred, the reasons for delay, and the technical specialty or rating which performed the maintenance.

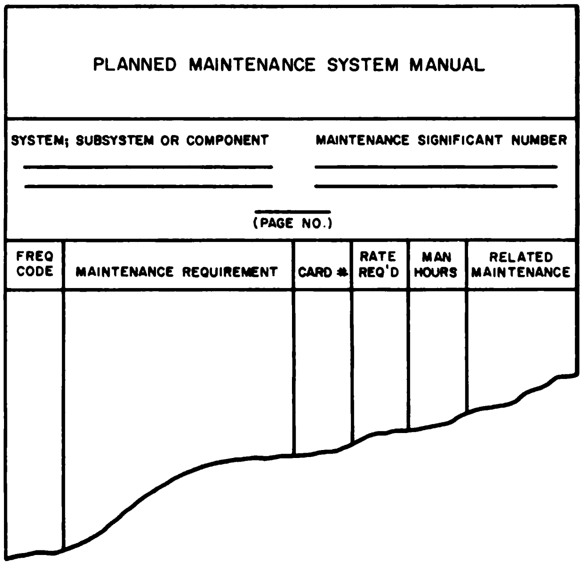
Analysis of information of maintenance will permit vital knowledge on mean times between failures, proper checks to be made to compare with standards, frequency of checks, development of better lubricants, increased supply support, increased or decreased personnel, etc.

TOOLS OF PMS

The primary tools of PMS are: the maintenance manual, the cycle schedule, the quarterly schedule, the weekly schedule, and the Maintenance Requirement Card (MRC).

The Planned Maintenance System Manual contains all the minimum preventive maintenance requirements that have been compiled from all technical manuals. It is used for ready reference in conjunction with planning and scheduling by the weapons officer and his maintenance group supervisors (a maintenance group is a group within the weapons department, e.g. fire control, deck, guns, etc.). The manual consists of a manual index, with a page for each component within the group, which has a short description of each maintenance task required. A code indicates whether the task is done daily, weekly, monthly, etc., and the average time per person required to perform the task is listed. Each page also lists the rate that should perform the task and the Maintenance Requirement Card (MRC) which spells out the maintenance requirement in greater detail. The following illustration is an example of a typical page.

The Cycle Schedule itemizes preventive maintenance requirements (except daily and weekly) based on the ship's overhaul cycle. It lists the components aboard and their semi-annual, annual, and overhaul cycle requirements by "quarters after overhaul". It lists only the quarterly and the monthly jobs that must be scheduled each quarter. The cycle schedule is used by the scheduling officer aboard to make out each quarter's preventive maintenance schedule, and is shown to the right.



PLANNED MAINTENANCE SYSTEM MANUAL

SYSTEM; SUBSYSTEM OR COMPONENT ______ MAINTENANCE SIGNIFICANT NUMBER ______

(PAGE NO.)

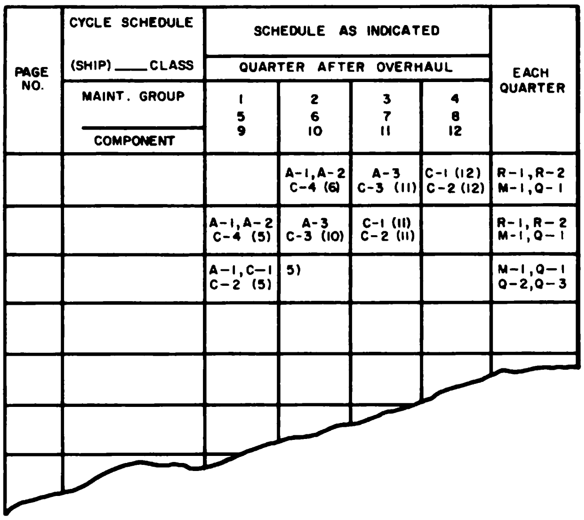
FREQ CODE	MAINTENANCE REQUIREMENT	CARD #	RATE REQ'D	MAN HOURS	RELATED MAINTENANCE

FREQUENCY CODE (M. R. NUMBER)

D– DAILY
W– WEEKLY
M– MONTHLY
Q– QUARTERLY
S– SEMI-ANNUALLY

A– ANNUALLY
C– OVERHAUL CYCLE (ONCE EVERY 3 YEARS)
R– SITUATION REQUIREMENT, I.E., 100 HR., PRE-FIRING, PRIOR TO GETTING UNDERWAY.

52. SAMPLE PAGE FROM PLANNED MAINTENANCE SYSTEM MANUAL



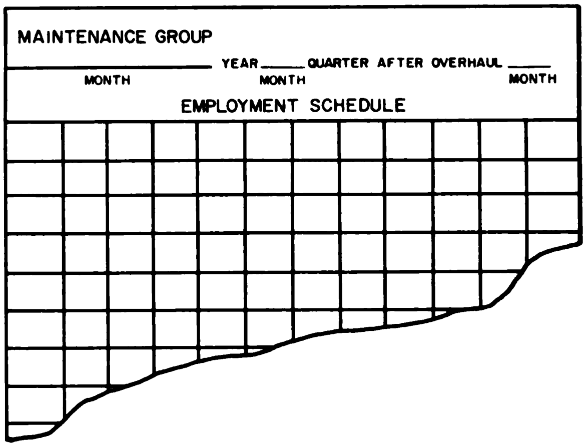
PAGE NO.	CYCLE SCHEDULE (SHIP) ____ CLASS	SCHEDULE AS INDICATED				EACH QUARTER
		QUARTER AFTER OVERHAUL				
	MAINT. GROUP COMPONENT	1 5 9	2 6 10	3 7 11	4 8 12	
			A-1, A-2 C-4 (6)	A-3 C-3 (11)	C-1 (12) C-2 (12)	R-1, R-2 M-1, Q-1
		A-1, A-2 C-4 (5)	A-3 C-3 (10)	C-1 (11) C-2 (11)		R-1, R-2 M-1, Q-1
		A-1, C-1 C-2 (5)	5)			M-1, Q-1 Q-2, Q-3

WHERE USED: POSTED ON A SCHEDULE DISPLAY BOARD AS PART OF THE LONG RANGE SCHEDULE.

WHEN USED: USED IN QUARTERLY SCHEDULING OF THE PREVENTIVE MAINTENANCE TASKS.

WHO USES: DEPARTMENT HEAD, DIVISION OFFICERS AND MAINTENANCE GROUP SUPERVISORS.

53. CYCLE SCHEDULE



MAINTENANCE GROUP

______ YEAR ______ QUARTER AFTER OVERHAUL ______

MONTH MONTH MONTH

EMPLOYMENT SCHEDULE

WHERE USED: POSTED ON THE SCHEDULE DISPLAY BOARD.

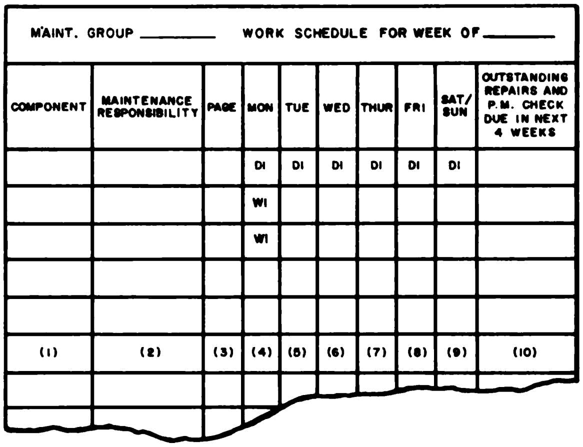
WHEN USED: USED IN QUARTERLY SCHEDULING AND WEEKLY SCHEDULING.

WHO USES: USED BY DEPARTMENT HEAD, DIVISION OFFICERS, AND MAINTENANCE GROUP SUPERVISORS.

54. QUARTERLY SCHEDULE

The Quarterly Schedule (shown above) contains thirteen columns, one for each week in the current quarter, and enables scheduling of all maintenance requirements on a weekly basis throughout the quarter's three months, and includes both the requirements from the cycle schedule and those weekly and daily checks that are needed. The quarterly schedule for the following quarter is placed to the right of the current quarterly schedule on an appropriate bulletin board for ease of promulgation and planning. This display of the cycle schedule, current quarter schedule, and subsequent quarter schedule may be referred to as a long range schedule. At the end of each week the maintenance group supervisor will cross out all the maintenance requirements which have been accomplished during the last week by the use of an (X). He will circle (0) all requirements which have not been accomplished. These circled requirements must be rescheduled and, thereby, the weekly schedule is used to update the current quarter schedule each week. Any semi-annual, annual, or overhaul cycle requirement which cannot be accomplished during the current quarter shall be rescheduled on the subsequent quarter schedule. The completed quarter schedule is removed from the display board and retained as a preventive maintenance record after the close of each quarter. This record may be discarded at the beginning of the second quarter after the next overhaul.

The Weekly Schedule (shown below) is another visual chart. It is posted in each maintenance group's (in this case the FTs) working area. It assigns specific personnel to perform required maintenance on specific components listed on a particular page of the maintenance manual. Each day of the week is listed on the same line as the individual responsible and the equipment he is to do preventive maintenance upon. The tasks to be done daily are listed for each day of the current week and the weekly, monthly, or other periodic maintenance requirements are spread throughout the week. When the man responsible for the Maintenance Requirement (MR) accomplishes his job, he marks the maintenance requirement number out with an (X); it will be circled when the maintenance cannot be completed. The maintenance group supervisor reschedules all circled items as his workload and ship's operations allow. At the end of each week the supervisor brings



MAINT. GROUP ______ WORK SCHEDULE FOR WEEK OF ______

COMPONENT	MAINTENANCE RESPONSIBILITY	PAGE	MON	TUE	WED	THUR	FRI	SAT/SUN	OUTSTANDING REPAIRS AND P.M. CHECK DUE IN NEXT 4 WEEKS
			DI	DI	DI	DI	DI	DI	
			WI						
			WI						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

FORMAT INCLUDES ALL DAILY AND WEEKLY CHECKS PREPRINTED

WHERE USED: POSTED IN MAINTENANCE GROUP WORK SPACE IN ALUMINUM HOLDER.

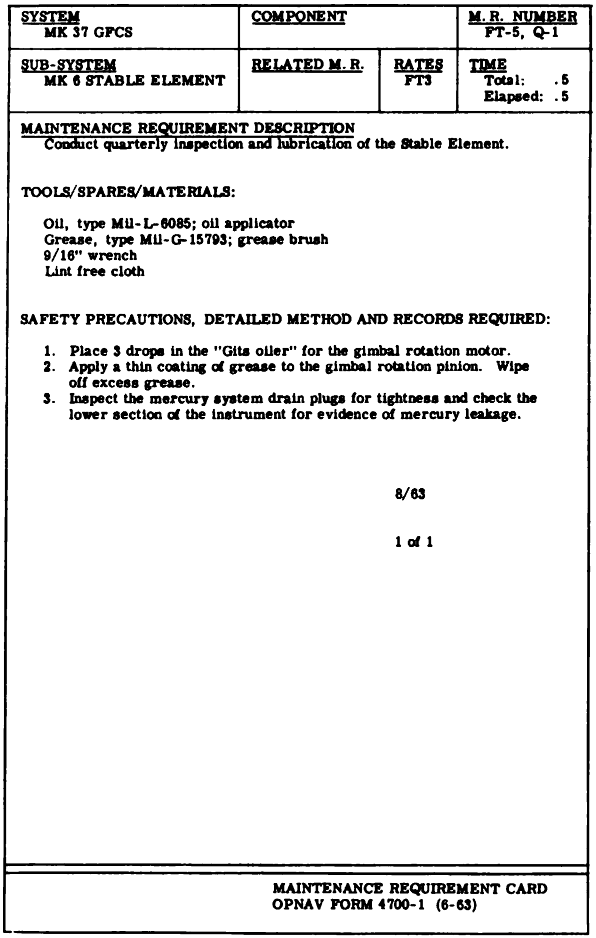
WHEN USED: USED TO SCHEDULE WORK IN SPACES.

WHO USES: MAINTENANCE GROUP SUPERVISORS AND MAINTENANCE PERSONNEL.

55. WEEKLY SCHEDULE

his quarterly schedule up to date utilizing his weekly schedule. He then cleans off the old weekly schedule and prepares the next week's; this is easily done because the chart is made of plastic.

A sample Maintenance Requirement Card (MRC) is shown below. When it is time for the individual technician to accomplish a scheduled maintenance requirement, he pulls the particular MRC for that task. The MRC is a standardization of the procedures required to do a job in the best known way. It expedites the accomplishment of the task, states the tools to be used, and the safety precautions to be considered. The MRC is a 5" by 8" card (OPNAV FORM 4700-1) and concerns areas of inspection, testing, and adjustments, lubrication, replacement, and cleaning. It also lists the job frequency, level of skill required, manhours, and total elapsed time.



SYSTEM MK 37 GFCS	COMPONENT		M. R. NUMBER FT-5, Q-1
SUB-SYSTEM MK 6 STABLE ELEMENT	RELATED M. R.	RATES FT3	TIME Total: .5 Elapsed: .5

MAINTENANCE REQUIREMENT DESCRIPTION
Conduct quarterly inspection and lubrication of the Stable Element.

TOOLS/SPARES/MATERIALS:

Oil, type Mil-L-6085; oil applicator
Grease, type Mil-G-15793; grease brush
9/16" wrench
Lint free cloth

SAFETY PRECAUTIONS, DETAILED METHOD AND RECORDS REQUIRED:

1. Place 3 drops in the "Gits oiler" for the gimbal rotation motor.
2. Apply a thin coating of grease to the gimbal rotation pinion. Wipe off excess grease.
3. Inspect the mercury system drain plugs for tightness and check the lower section of the instrument for evidence of mercury leakage.

8/63

1 of 1

MAINTENANCE REQUIREMENT CARD
OPNAV FORM 4700-1 (6-63)

WHERE USED: MASTER SET BY DEPARTMENT HEAD, WORKING SET IN WORK SPACE.

WHEN USED: IN PLANNING AND SCHEDULING AND IN ACTUAL PERFORMANCE OF JOB.

WHO USES: DEPARTMENT HEAD, DIVISION OFFICER, CHIEF PETTY OFFICER, MAINTENANCE GROUP SUPERVISOR AND WORKING MAN.

56. SAMPLE MRC WITH ENTRIES

Each working day the FT should consult the weekly schedule and see what his leading petty officer has him personally scheduled to accomplish. A complete working set of maintenance requirement cards will be located in the FT area. The technician will perform the following steps:

1. Remove the pertinent card from working set of MRCs.
2. Obtain stated tools/spares/material.
3. Perform the maintenance requirements as specified on the MRC, observing safety precautions.
4. Return the card to the container after completion of all items listed on the MRC.
5. Cross off the maintenance requirement listed on the weekly schedule.
6. During the performance of a maintenance requirement, if any potential casualty, corrective maintenance or deficiency is noted, notify the maintenance group supervisor.
7. Any discrepancies in the MRC caused by peculiarities in the ship installation (wrong wrench size for a component, improper references, etc.) shall be reported to the maintenance group supervisor who will verify and correct the master set.
8. A master set of MRCs is maintained in the weapons office so that duplicates for lost cards can be made. The master manual is also located in that office.

With specific reference to the MRC, certain terms require definition:

Weapon System: a class of combatant ship or aircraft, e.g., DDG, DLG, CG, DEG, etc.

System: a major part of the weapons system which performs a specific function, e.g., Mk 74 GMFCS, Mk 4 WDS, Mk 11 GMLS, etc.

Sub-System: a part of a system which is essentially a complete unit within the system, e.g., Mk 118 Computer, Mk 73 Director, etc.

Component: a part of a sub-system capable of independent operation, e.g., a power drive in a launcher, a CWI Transmitter, the WDS Master Power Panel, etc.

In accordance with OPNAV INST 4000.17, the following, which is a minimum of information, appears on a MRC:

System: will use appropriate abbreviation, e.g., Mk 37 GFCS.

Sub-System: e.g., Mk 6 Stable Element.

Component: may or may not exist; identification may go to the component, e.g., train power drive, or identification may remain at the sub-system level if it is more appropriate, e.g., Mk 6 Stable Element.

MR Number: this is the maintenance requirement number and usually refers to that as listed in the manual index in the master manual, e.g., FT5, as well as another set to indicate the frequency code, e.g., D for daily, W for weekly, M for monthly, Q for quarterly, S for semi-annually, A for annually, C for overhaul cycle, and R for situational (every 100 hours, pre-firing, etc.). This is also listed on the schedules, e.g., Q-1.

Related MR: this lists an MR which needs to be accomplished prior to, in conjunction with, in place of, or after the task to be performed in the above paragraph.

Rates: number of men by rate of the lowest skill level required to perform the maintenance action.

Time: lists in man-hours and tenths, that which is required to accomplish the task and the total elapsed time for accomplishment with the number of personnel indicated in "Rates". The time of petty officers' supervisory functions and administrative time in assembly of materials will not be included.

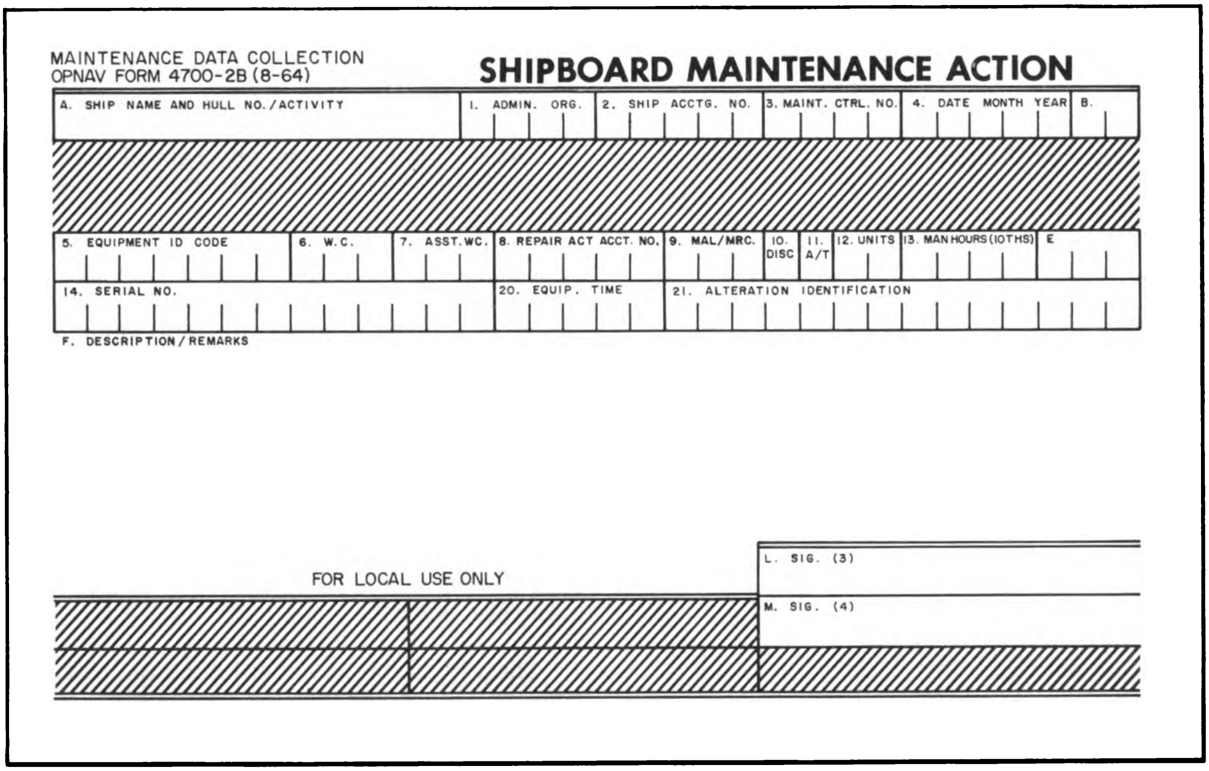
Maintenance Requirement Description: is a brief word description of the maintenance action for quick identification and usually begins with an action verb, e.g., inspect, calibrate, adjust, etc.

The rest of the card will contain, where appropriate, Tools/Spares/Materials, Safety Precautions, Location, and Detailed Method of accomplishment in step by step detail. This procedure is followed by the issue of the card and any change number indications.

TOOLS OF MDC

The three documents used to record maintenance actions are briefly described below:

OPNAV FORM 4700-2B (Shipboard Maintenance Action) - A single copy form as shown below is used to record the completion of certain planned maintenance actions, a corrective maintenance action, or an authorized alteration that has been done by shipboard personnel.



MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2B (8-64)

SHIPBOARD MAINTENANCE ACTION

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE MONTH YEAR	B.

5. EQUIPMENT ID CODE	6. W.C.	7. ASST. WC.	8. REPAIR ACT ACCT. NO.	9. MAL/MRC.	10. DISC	11. A/T	12. UNITS	13. MAN HOURS (10THS)	E

14. SERIAL NO.	20. EQUIP. TIME	21. ALTERATION IDENTIFICATION

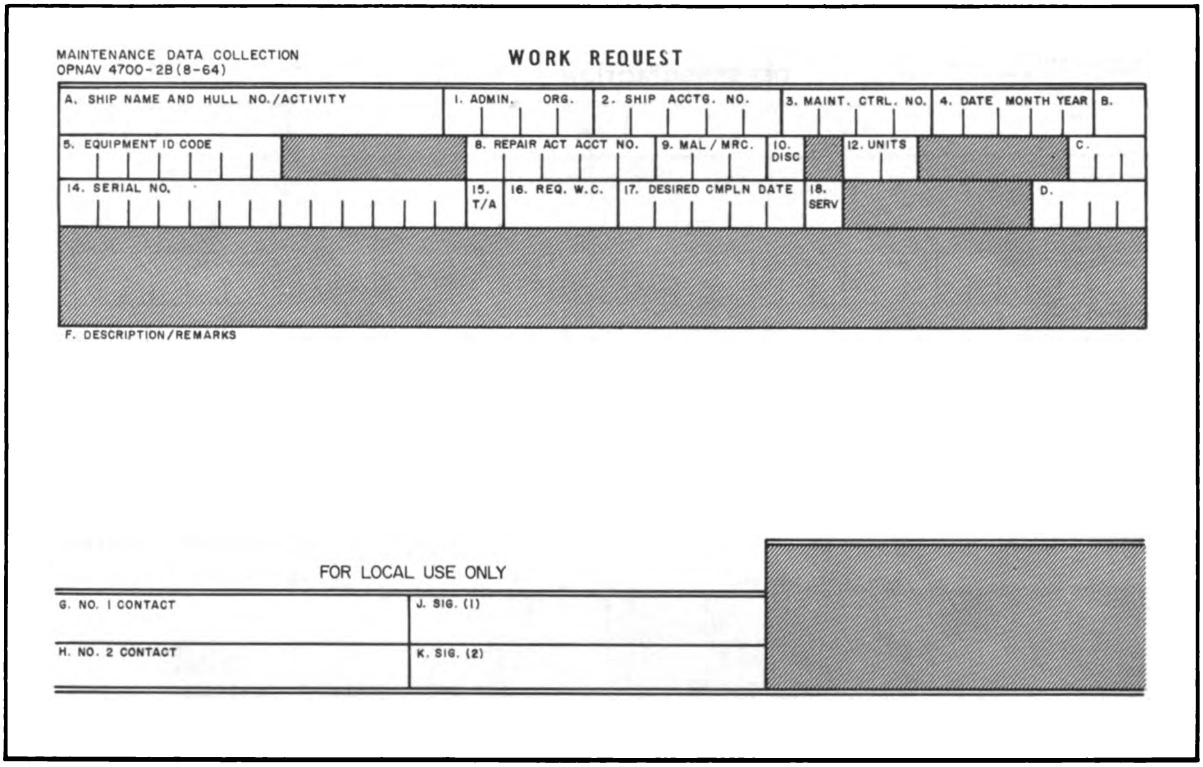
F. DESCRIPTION / REMARKS

FOR LOCAL USE ONLY

L. SIG. (3)

M. SIG. (4)

57. SHIPBOARD MAINTENANCE ACTION



MAINTENANCE DATA COLLECTION
OPNAV 4700-2B (8-64)

WORK REQUEST

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE MONTH YEAR	B.
5. EQUIPMENT ID CODE	8. REPAIR ACT ACCT NO.	9. MAL / MRC.	10. DISC	12. UNITS	C.
14. SERIAL NO.	15. T/A	16. REQ. W.C.	17. DESIRED CMPLN DATE	18. SERV	D.

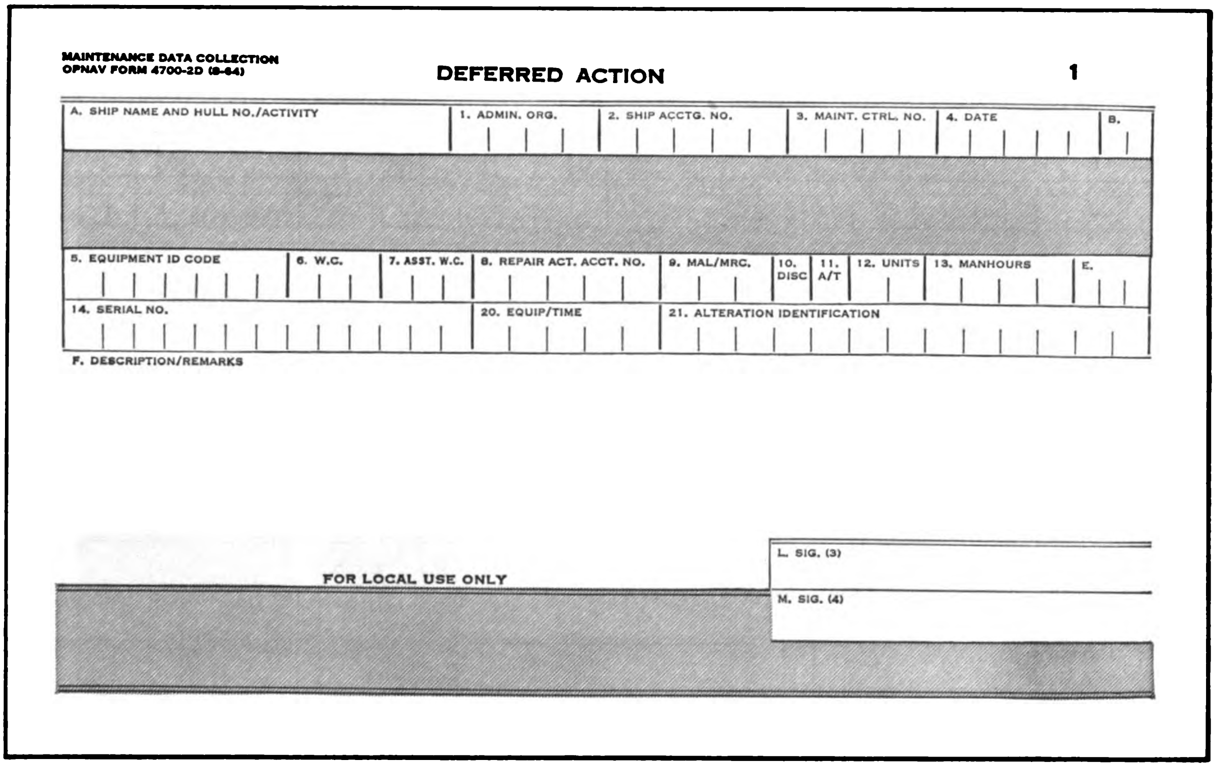
F. DESCRIPTION/REMARKS

FOR LOCAL USE ONLY

G. NO. 1 CONTACT	J. SIG. (1)
H. NO. 2 CONTACT	K. SIG. (2)

58. WORK REQUEST

OPNAV FORM 4700-2C (Work Request) - A four part form as shown above is used as a work request for outside assistance and for final documentation of action taken to complete the maintenance requested of the repair activity. This form is used to request assistance from repair activities other than shipyards. They will be submitted for repair activity assistance and all scheduled availabilities. The work request will be forwarded as directed by Type Commanders. The timely submission of this form is to the advantage of the ship requesting assistance. This permits the repair activity to schedule work, procure materials where feasible, assign any availabilities necessary to other repair activities, and determine special time consuming problems. Form 4700-2C (Part II) is an additional form to provide a more complete written description of the work request.



MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2D (8-64)

DEFERRED ACTION

1

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE	B.

5. EQUIPMENT ID CODE	6. W.C.	7. ASST. W.C.	8. REPAIR ACT. ACCT. NO.	9. MAL/MRC.	10. DISC	11. A/T	12. UNITS	13. MANHOURS	E.

14. SERIAL NO.	20. EQUIP/TIME	21. ALTERATION IDENTIFICATION

F. DESCRIPTION/REMARKS

L. SIG. (3)

FOR LOCAL USE ONLY

M. SIG. (4)

59. DEFERRED ACTION

OPNAV FORM 4700-2D (Deferred Action) - A two part form as shown above is used to record the fact that a maintenance action has been started and manhours expended, and that the action must be deferred due to ship's operations, lack of spare parts, or the requirement for outside assistance (tender, MOTU, shipyard, etc.). The form is in two parts so that the first copy is filled in, reporting the beginning action. The second copy, identical to the first, is filled in on completion of the deferred action. Information and times relating to maintenance action deferrals can be analyzed from it.

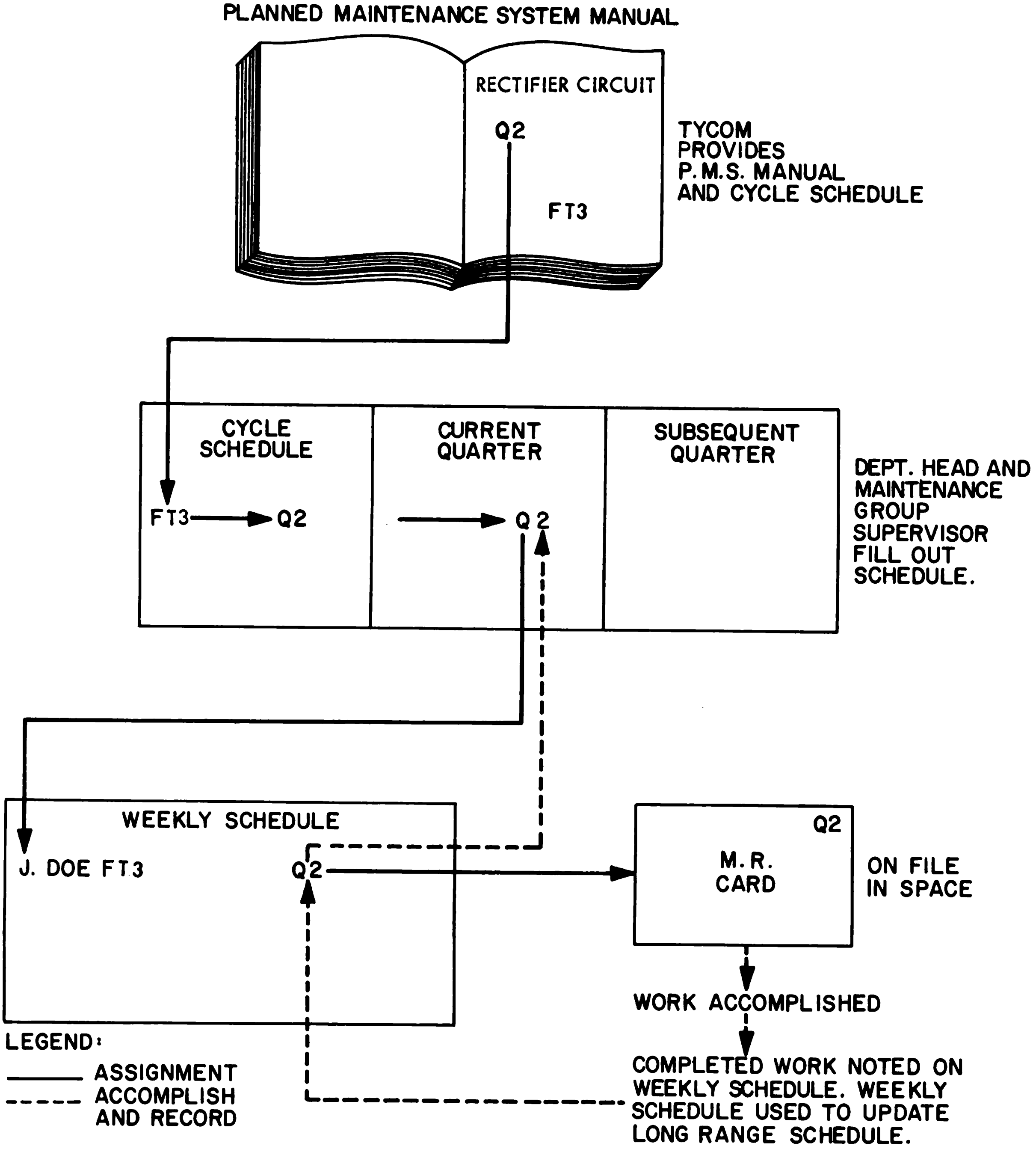
REVIEW AND SUMMARY

The planned maintenance system is designed to provide management tools to plan, direct, and control the preventive maintenance of all systems, sub-systems, and components installed. The program reduces the maintenance of complex equipment to detailed procedures carried out under a workable plan. It defines the preventive maintenance to be performed, schedules the maintenance at regular intervals, states methods for performing the maintenance (task) and provides for taking action on casualties and deficiencies. It also affords the department head the opportunity to delegate defined responsibility and observe the results.

The training aspects of this program should be emphasized. The MRCs provide the same information for on-the-job training as is normally presented at equipment maintenance schools.

In conjunction with the planned maintenance system, a feedback system, known as maintenance data collection, will be utilized. MDC will provide a means of evaluating equipment performance to determine: reliability of equipment, quality of maintenance and operating personnel, adequacy of training provided by Navy schools, proper usage of equipment, manpower requirements, realistic maintenance requirements, and adequacy of spare parts and supplies.

The various steps involved in the completion of a maintenance task, from the planned maintenance manual to the actual completion on the equipment and notations on the various schedules, is illustrated on the facing page.


PLANNED MAINTENANCE SYSTEM MANUAL
RECTIFIER CIRCUIT
Q2
FT3
TYCOM PROVIDES P.M.S. MANUAL AND CYCLE SCHEDULE
CYCLE SCHEDULE
CURRENT QUARTER
SUBSEQUENT QUARTER
FT3
Q2
Q 2
DEPT. HEAD AND MAINTENANCE GROUP SUPERVISOR FILL OUT SCHEDULE.
WEEKLY SCHEDULE
J. DOE FT3
Q2
Q2
M.R. CARD
ON FILE IN SPACE
WORK ACCOMPLISHED
COMPLETED WORK NOTED ON WEEKLY SCHEDULE. WEEKLY SCHEDULE USED TO UPDATE LONG RANGE SCHEDULE.
LEGEND:
ASSIGNMENT
ACCOMPLISH AND RECORD

60. FLOW DIAGRAM OF PLANNED MAINTENANCE SYSTEM REQUIREMENT

QUIZ:

1. What are the two divisions of NMMS?

2. The long range schedule is a display of which schedules?

3. What information is needed to enable a supervisor to compile the quarterly schedule?

4. Where is the information on the ship's operating schedule displayed in the NMMS?

5. Which schedule would a striker look at in order to determine if he has been assigned a PM check?

6. Where would the striker find the information required to accomplish an assigned PM check?

7. Who maintains control of the master PMS manual for fire control equipment?

Section 3

NAVAL SUPPLY SYSTEM

Topic No.	Topic Title	Page
1.	The Supply Department	68
2.	The FT and the Supply Department	70

TOPIC 1: THE SUPPLY DEPARTMENT

YOU ARE NOW GOING TO LEARN:

1. The supply department afloat.
2. What storekeepers do.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Organization of the supply department.
2. Responsibility of stores component.
3. What storekeepers do.
4. Review and summary.

INFORMATION AND DISCUSSION:

ORGANIZATION OF THE SUPPLY DEPARTMENT

The supply department aboard ship is responsible for the procurement, receipt, inspection, storage, and issue of all materials (except medical supplies, Marine corps supplies, and ammunition).

At right is shown the four components of the supply department commonly found on a large ship. These are disbursing, commissary, stores, and ship's store stock and clothing and small stores.

You are not directly concerned with the first, second, and fourth components; but let us turn our attention to the third one, labeled "stores".

RESPONSIBILITY OF STORES COMPONENT

Looking at the Stores Section Chart, study carefully the stores component. The stores component receives, stows, and expends general stores and repair parts. It also prepares correspondence, stores returns, and all necessary supply records. There are two sections in the stores component: records and returns, and storage.

The records and returns section requisitions general stores and repair parts, and maintains office records for general stores, repair parts, and equipage. It performs obligatory recordings and maintains stock records. In addition, this section prepares correspondence and makes supply reports.

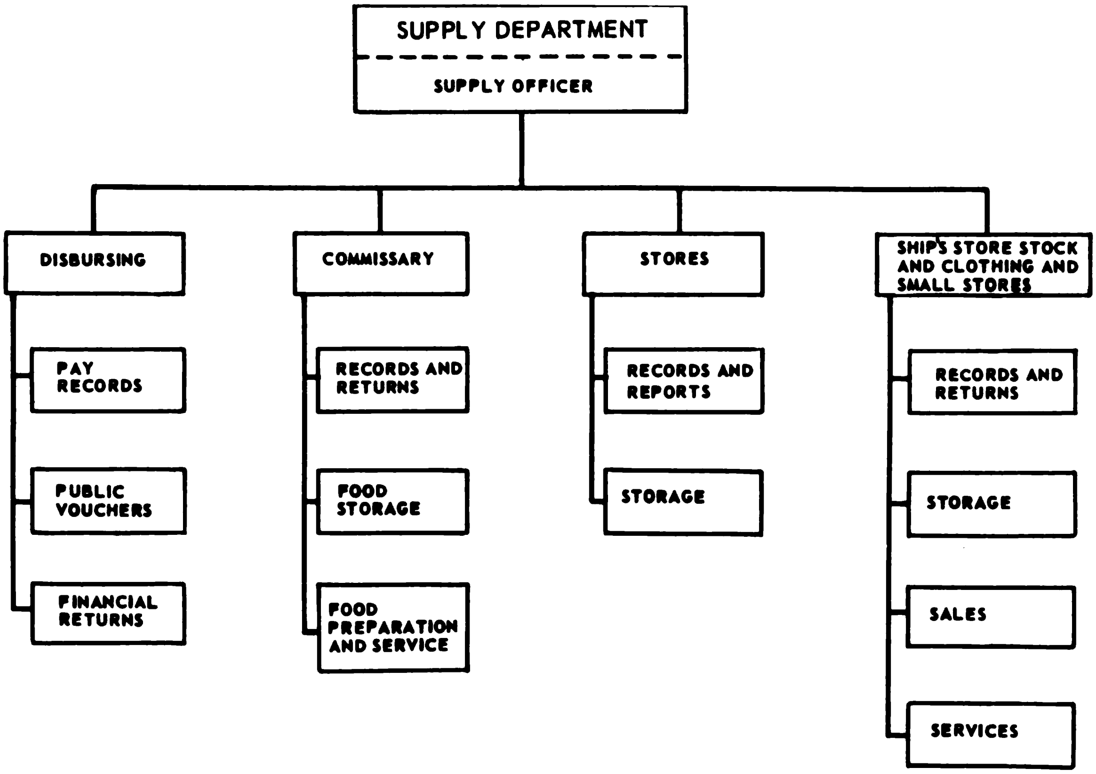
The storage section receives, stows, and issues general stores and repair parts. It also maintains assigned spaces and records pertaining to the operation of the section.

WHAT STOREKEEPERS DO

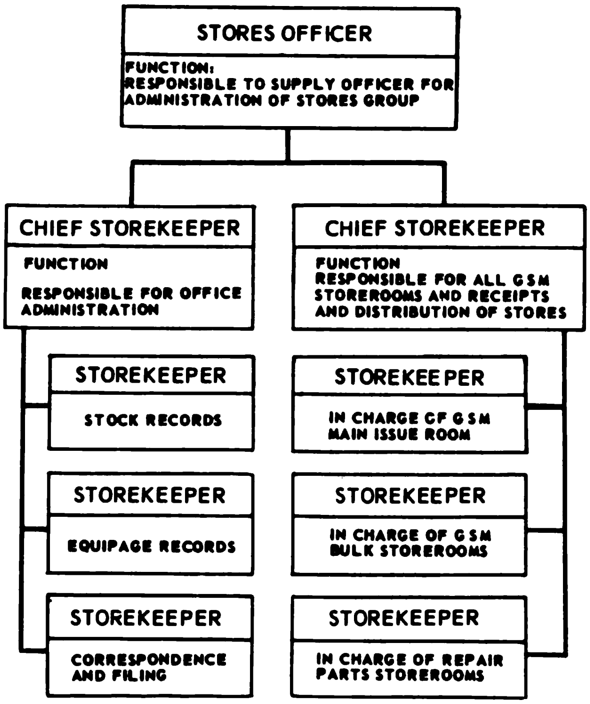
Now that you know something about the supply department with which you will work, let us consider the duties the storekeeper performs in this organization. Generally speaking, his technical or professional duties include the following: identifying materials, procuring materials, stowing materials, issuing materials, and accounting for materials. Obviously a storekeeper has many duties of a secondary nature but these will not be listed here.

REVIEW AND SUMMARY

The organization of the supply department and the procedures used for ordering of various materials may vary slightly from ship to ship. The important thing for you to remember, however, is to adhere to the procedures used aboard your own ship. Your work and the work of the storekeepers will be much easier if you cooperate. Be sure you have ALL the correct information you can obtain for anything you wish to order. The more information you can provide the better the results.



61. TYPICAL SUPPLY DEPARTMENT AFLOAT


STORES OFFICER
FUNCTION:
RESPONSIBLE TO SUPPLY OFFICER FOR ADMINISTRATION OF STORES GROUP
CHIEF STOREKEEPER
FUNCTION
RESPONSIBLE FOR OFFICE ADMINISTRATION
CHIEF STOREKEEPER
FUNCTION
RESPONSIBLE FOR ALL GSM STOREROOMS AND RECEIPTS AND DISTRIBUTION OF STORES
STOREKEEPER
STOCK RECORDS
STOREKEEPER
EQUIPAGE RECORDS
STOREKEEPER
CORRESPONDENCE AND FILING
STOREKEEPER
IN CHARGE OF GSM MAIN ISSUE ROOM
STOREKEEPER
IN CHARGE OF GSM BULK STOREROOMS
STOREKEEPER
IN CHARGE OF REPAIR PARTS STOREROOMS

62. STORES SECTION

TOPIC 2: THE FT AND THE SUPPLY DEPARTMENT

YOU ARE NOW GOING TO LEARN:

1. How to request material from the supply department.
2. How to identify ordnance materials.
3. What COSAL is and how it is used.
4. The terms used in equipment subject breakdown.

DISCUSSION POINTS FOR THIS TOPIC ARE:

1. Requesting information from the supply department.
2. Preparation of NAVSANDA FORM 1250.
3. What the storekeepers do with NAVSANDA FORM 1250.
4. How to identify ordnance materials.
5. COSAL.
6. Equipment subject breakdown.
7. Review and summary.

INFORMATION AND DISCUSSION:

REQUESTING MATERIAL FROM THE SUPPLY DEPARTMENT

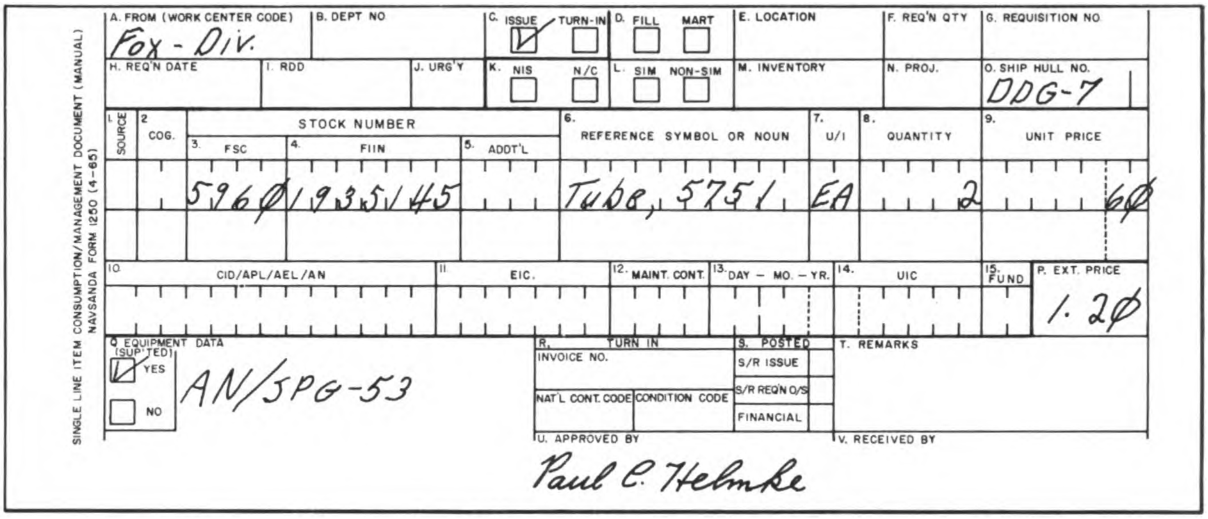
In your relations with the storekeeper you will be concerned with his duties as they cross over into the weapons department. As an FT you will probably be required to make out most of the forms needed to order repair parts, equipage, or materials such as grease, oil, and tools. It will be helpful therefore, if you understand the correct procedures for drawing material from the supply department and for using the appropriate forms.

PREPARATION OF NAVSANDA FORM 1250

The form used for making requests of material from the supply department is NAVSANDA FORM 1250, shown on the facing page. Complete instructions for filling out this form are contained in BUSANDA Notice 4406 of 19 May 1965. Though the storekeeper is responsible for much of the information on the card, the man requesting the part or supplies must fill in enough to enable the storekeeper to know what is needed. A separate form must be used for each item.

To illustrate, assume that you require two 5751 vacuum tubes to repair the AN/SPG-53 Radar. The request for the item officially begins in the weapons office. The FT will fill in the form 1250 as shown on the facing page. The division is noted in block A, "issue" is checked in block C and the ship hull number entered in block O. The stock number, if known, is entered in blocks 3 and 4. It will save time and insure that the right material is issued, if the stock number is entered by the requester. The weapons office will have some Federal Stock catalogs, as well as other sources of these stock numbers (to be covered later in this topic). To eliminate confusion between zeros and the letter "O", use the communication Ø for zero. In block G enter the noun name of the item or, if electronics equipment under MDC, the circuit symbol number. In block 7 enter the unit of issue; ea for each, bx for box, dz for dozen, gr for gross, lb for pound, gl for gallon, etc. The desired quantity is shown in box 8 and the unit price, if known is entered in 9. Block P, ext. price, is the unit price times the quantity. The equipment data in block Q will aid the Storekeeper in determining the proper sources of additional information on the material ordered.

When as much information as possible has been entered on the form 1250, it must be signed by the Weapons Officer, or other person designated to approve issues of material. The request is now ready to take to the supply office.



SINGLE LINE ITEM CONSUMPTION/MANAGEMENT DOCUMENT (MANUAL)
NAVSANDA FORM 1250 (4-65)

A. FROM (WORK CENTER CODE) Fox - Div.	B. DEPT NO	C. ISSUE ☑ TURN-IN ☐	D. FILL ☐ MART ☐	E. LOCATION	F. REQ'N QTY	G. REQUISITION NO
H. REQ'N DATE	I. RDD J. URG'Y	K. NIS ☐ N/C ☐	L. SIM ☐ NON-SIM ☐	M. INVENTORY	N. PROJ.	O. SHIP HULL NO. DDG-7

1. SOURCE	2 COG.	STOCK NUMBER 3. FSC	STOCK NUMBER 4. FIIN	STOCK NUMBER 5. ADDT'L	6. REFERENCE SYMBOL OR NOUN	7. U/I	8. QUANTITY	9. UNIT PRICE
		5960	1935145		Tube, 5751	EA	2	60

10. CID/APL/AEL/AN	11. EIC.	12. MAINT. CONT.	13. DAY – MO. – YR.	14. UIC	15. FUND	P. EXT. PRICE
						1.20

Q EQUIPMENT DATA (SUP'TED)
☑ YES
☐ NO
AN/SPG-53

R. TURN IN
INVOICE NO.
NAT'L CONT. CODE
CONDITION CODE

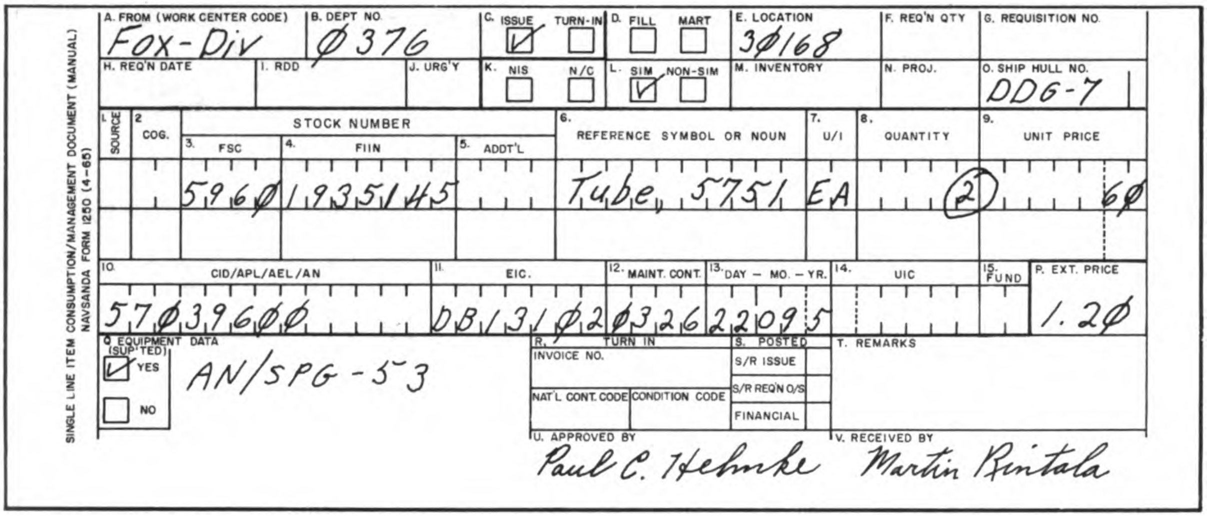
S. POSTED
S/R ISSUE ☐
S/R REQ'N O/S ☐
FINANCIAL ☐

T. REMARKS

U. APPROVED BY
Paul C. Helmke

V. RECEIVED BY

63. PREPARATION OF NAVSANDA FORM 1250 BY WEAPONS DEPARTMENT



SINGLE LINE ITEM CONSUMPTION/MANAGEMENT DOCUMENT (MANUAL)
NAVSANDA FORM 1250 (4-65)

A. FROM (WORK CENTER CODE) Fox-Div
B. DEPT NO. 0376
C. ☑ ISSUE ☐ TURN-IN
D. ☐ FILL ☐ MART
E. LOCATION 30168
F. REQ'N QTY
G. REQUISITION NO.
H. REQ'N DATE
I. RDD
J. URG'Y
K. ☐ NIS ☐ N/C
L. ☑ SIM ☐ NON-SIM
M. INVENTORY
N. PROJ.
O. SHIP HULL NO. DDG-7

1. SOURCE	2 COG.	STOCK NUMBER 3. FSC	STOCK NUMBER 4. FIIN	STOCK NUMBER 5. ADDT'L	6. REFERENCE SYMBOL OR NOUN	7. U/I	8. QUANTITY	9. UNIT PRICE
		5960	1935145		Tube, 5751	EA	(2)	60

10. CID/APL/AEL/AN	11. EIC.	12. MAINT. CONT.	13. DAY – MO. – YR.	14. UIC	15. FUND	P. EXT. PRICE
57039600	DB13102	0326	22095			1.20

Q EQUIPMENT DATA (SUP'TED) ☑ YES ☐ NO AN/SPG-53
R. TURN IN INVOICE NO.
NAT'L CONT. CODE
CONDITION CODE
S. POSTED S/R ISSUE
S/R REQ'N O/S
FINANCIAL
T. REMARKS
U. APPROVED BY Paul C. Hehmke
V. RECEIVED BY Martin Rintala

64. PROCESSING NAVSANDA FORM 1250 IN SUPPLY OFFICE

WHAT THE STOREKEEPERS DO WITH NAVSANDA FORM 1250

In the supply office the SK:

1. Checks the form 1250 to see that it is properly prepared and bears an authorized signature.
2. Checks to see the material is properly identified and that the unit price and extended total price are correct.
3. Checks the stock records also to see if the material requested is available, in stock.
4. Assigns the next number in the department's series to the request and enters it in the issue record book.
5. Checks to see if requested material is in critical supply. If so, it will not be issued without prior approval of the supply officer or his designated officer assistant.
6. Checks to see that the department operating budget has enough unobligated balance to cover the value of the issues; obligates if an order is made.

When the SK in the supply office finishes, the FT takes the requisition to another SK in the storeroom. This SK does the following:

1. Checks whether there is a directive limiting issues of the material.
2. Draws the items from bins.
3. Encircles quantities of items as issued on the requisition.
4. Makes the issue and gets the FT's signature as a receipt for the material.

HOW TO IDENTIFY ORDNANCE MATERIALS

The flow of the requisition in the preceding example was smooth as it traveled through the weapons and supply departments; but this is not always the case. The SK sometimes has trouble identifying the items ordered. He cannot just look at the name of an item or at the item itself and decide what it is or what it should have been called. He must identify the item in accordance with the Navy practice of assigning the same identification data to identical stock, so that all persons concerned will use the same name, description, and number when referring to the same item. It is when the SK has trouble identifying materials that you can help him. If the SK does not have a correct stock number, nomenclature, etc., for required materials, you may assist him by providing information, as applicable, from the following sources:

1. Ordnance equipment and components - Each piece of ordnance equipment is identified by a MARK and MOD number or a JAN identification stamped on a nameplate. In addition, equipments are generally identified by a serial number; and the name of the manufacturer is stamped on the nameplate.

2. Ordnance repair parts - Ordnance repair parts, depending on their nature, may be identified by stamping or etching on the part itself, or on the outside wrapping of the part. The identification may be a stock number of one kind or another, a manufacturer's part or reference number, manufacturer's drawing number, or a BUWEPS drawing number.

3. Standard Naval Identification Tables (SNIT List) - These are issued for individual electronics equipments. These tables contain a cross-reference between the parts symbol number (R4, C101, etc.) for each unit of an equipment, to the Federal Stock Number (FSN) used for requisitioning the part from supply. This is the quickest way of obtaining this information. Unfortunately, SNIT lists are not available for all equipments. If SNIT lists are available, one copy will usually be retained by the SK and another copy will usually be retained in the weapons office.

4. COSAL (Coordinated Ship's Allowance List) - Your ship's COSAL is one of the chief sources of information. It lists all authorized ordnance equipment, repair parts, and consumable supplies authorized for your ship.

5. Ordnance Alterations (OrdAlts) - These give instructions for making alterations to ordnance equipment. Since they contain the latest manufacturer's number assigned to a piece of equipment or subassembly, they are useful for identification purposes.

6. Bureau of Naval Weapons Instructions and Notices - These publications cover general policy matter of BUWEPS, but they also contain information relating to the operation and capabilities of ordnance equipment.

7. Ordnance Pamphlets (OP's) - These are published by BUWEPS to provide detailed information pertaining to the proper use and repair of ordnance equipment.

8. List of Drawings (LD's) - These lists are made up for an assembly and provide the assembly's BUWEPS drawing number and the drawing number of each subassembly and/or part. These numbers are valuable because most drawing numbers are also reference numbers which the SK can cross-reference to a stock number. LD's for all ordnance equipment are filed at the ship's home yard.

COSAL

This system of supply was adopted to coordinate the material requirements of a ship. On a typical destroyer, different departments duplicate requirements of certain spare parts in varying amounts. Under the previous system of supply, each department took care of its own issuing, replacement, and stocking of repair and replacement parts. Because of this overlapping and duplication, there were washers, bolts, resistors, and capacitors not only used but stored, recorded, and requisitioned inefficiently. To prevent this waste, the COSAL system of supply and accounting was adopted.

COSAL is an allowance list prepared for an individual ship that considers all the ship's equipments. The list is divided by groups; i.e., Ordnance, Electronic, Electrical, Hull, Machinery, etc. The departments, weapons, operations, etc., each get their respective volumes.

Each COSAL has three parts. Part 1, Equipment Index, for storekeepers and technicians, lists all equipment installed aboard ship and gives the nomenclature and characteristics, and assigns an IDENTIFICATION NUMBER to each component listed. It also gives its service application - in other words tells which system it is a part of. Part 2, Allowance Parts List, primarily for technicians, gives the name of components, the technical manuals and blueprints that apply, the identification number, the manufacturer's number, and the Navy or Federal stock number which must be used for requisitioning. Part 3, Stock Number Sequence List, primarily for the storekeeper, gives these numbers in sequence, their nomenclature, and the system the components are used in. In an absolute emergency, Part 3 could be used to provide information which would lead to cannibalizing less critical equipment for required parts to keep a piece of critical equipment operating.

To use COSAL the procedure might be as follows:

1. Positively identify the component by using the technical manual or blueprints listed.
2. Look up the defective component in the Allowance Parts List.
3. If a part on the component is to be replaced, check the alphabetical listing of parts.
4. Obtain the Federal Stock Number (FSN) and/or Standard Navy Stock Number (SNSN) to requisition the replacement.
5. Turn the stock number in to the SK.

EQUIPMENT SUBJECT BREAKDOWN

You have used the terminology systems, assemblies, parts, etc., and in this topic on supply it may be well to define their exact relationship to one another. The following is an example of the Subjects and Identification Breakdown of an equipment:

1. System - Defined as related but not mechanically connected assemblies and parts, as a combination capable of performing a specific operational function or functions. Interconnection of assemblies by electrical cables or hydraulic transmission lines does not constitute mechanical connection. (Each variation of the system will be listed under 1.)
2. Major Assembly - Refers to an assembly identified by Mark and Mod (or equivalent designation) or to a complex assembly requiring the preparation of a List of Drawings. (Each major assembly or variation will be listed under 2.)
3. Assembly - Defined as mechanically connected subassemblies and parts, as a combination capable of performing a specific function. The distinction between an assembly and a subassembly is not always exact. (Each assembly will be listed under 3 after the major assembly that has it incorporated.)
4. Minor Assembly - Listed under 4 after the assembly that has it incorporated.
5. Subassembly - Defined as a combination of two or more mechanically connected parts that can be disassembled without destruction of designed usage. (Each subassembly will be listed under 5 after the assembly or minor assembly that has it incorporated.)
6. Groups of Related Parts - Listed after the component they connect.
7. Part (or Piece) - A single integral item, not capable of further subdivision, or a commercial item (such as a pressure gage) not normally taken apart during the service of the equipment that has it as a part. (Each will be listed after the component that has it incorporated.)

REVIEW AND SUMMARY

In this topic you were shown how an FT should prepare NAVSANDA Form 1250 to requisition material. You also saw how this form was processed through supply. It should be evident to you that the final result depends on cooperation. Several sources of information concerning nomenclature, stock numbers, etc., were listed. You as an FT should make every effort to use these sources to help the SK identify material which you requisition. The function and use of the COSAL system of supply was also illustrated and you should pay particular attention to this item. Terms used in an Equipment Subject Breakdown were defined and should be reviewed.

QUIZ:

1. Which section of the supply department is responsible for ordering and issuing replacement spare parts?

2. What is COSAL?

3. Which part or parts of COSAL would be used by a technician who requires a spare part?

4. Define a minor assembly.

5. Define a subassembly.

6. Who is responsible for obtaining the proper Federal Stock Number for an item listed on NAVSANDA Form 1250?

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.